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SPECIAL REVIEW

QUANTITATIVE COMMUNITY STUDIES OF LAND ANIMALS

BY J. RICHARD CARPENTER

(*Lincoln College, Oxford*)

(*With* 1 *Figure in the Text*)

A. INTRODUCTION

THERE has developed during the past twelve years a new method of dealing with the populations of the smaller animals of terrestrial biotic communities: quantitative analysis by various means of sampling, notably by the use of a given number of sweeps of an insect net. These methods grew up to meet the need felt by the Illinois group of "descriptive ecologists" of the period 1907–15 (Shelford, Adams, Vestal, Hart).

Early attempts at census taking in a quantitative manner were the investigations conducted by McAtee (1907) with ground samples, but work of this kind suffered a lapse until about ten years later when the papers on similar work by Beebe (1916) and Wolcott (1918) appeared. The first recorded attempt at using a sweep net for sampling populations was that of Sanders in 1914 (Sanders & Shelford, 1922) in the Chicago area. Since that time a coupling of the two methods, sweeping and ground sampling, has been successfully used by Weese, Smith Davidson, Shackleford, Brown, Blake, Rice, Bird, Beall, Hefley, and Carpenter in America; and by Gudoshchikova, and Baskina-Friedmann in the U.S.S.R.

It is the purpose of this paper to review the findings of these publications. This is done with the realization that the method presents certain limitations and certainly has not been without its critics (e.g. Banks, 1907, Gray & Treloar, 1933; DeLong, 1932). In the use of any quantitative samples, it should be remembered that too localized a study will not take into consideration minute differences caused by mosaics of local conditions, where ecologically equivalent species may supplant the usual species of the general area for a particular niche; that species fluctuate in numbers in any locality from year to year; and that an incorrectly sized sample may give erroneous ideas due to irregular or sparse distribution among the members of the population. A refinement of methods of sampling for each area should be striven for, and an examination of the population made frequently and, if possible, by more than one observer, to see that the size and number of samples is adequate (see Weese, 1936 (an elaboration of Kylin's method with reference to animal population studies); Carpenter & Ford, 1936; Carpenter, 1935 *a*; Beall, 1935;

and Zubareva, 1930). At all times quantitative sampling should be supplemented by cruising and observational notes in the style of the 1910–15 authors.

The data received from such a collecting method may be considered as "circumstantial" evidence of the population present, and must be interpreted with their limitations well in mind. It is contended by the author that few, if any, other sampling methods show a greater efficiency and convenience in practical usage than does the one described.

B. A conspectus of surveys embodying the sweep-net method

Below is included a synoptic list of detailed community studies employing quantitative analysis of the insect and Arachnid populations, chiefly by the sweep-net method (see Elton, 1933, pp. 17–18, for a list of the numbers of *species* found in a number of miscellaneous community surveys). For each study the following analysis of content and scope is used, so far as possible: (*a*) Community studied, (*b*) Location, (*c*) Year and duration of study, (*d*) Scope, (*e*) Method, (*f*) Results (number of species found, etc.). In all of the American studies the same sized net was used, one having a mouth of 14 in. and a handle about 30 in. long (described by Beall, 1935).

In the tables included for certain of the papers the following abbreviations for the "seasonal societies" are used: H. = Hiemal, P. = Prevernal, V. = Vernal, E. = Estival, S. = Serotinal, A. = Autumnal.[1] The original data of Weese (1924), Blake (1926), Smith (1928, Davidson 1930, 1932), Shackleford (1929), Bird (1930) and Rice (1932) may be consulted in their theses at the library of the University of Illinois, Urbana; those of Brown (1931), Carpenter (1935 *b*), and Hefley (1936) at the library of the University of Oklahoma, Norman; and that of Hendrickson (1930–31) at the University of Iowa, Ames.

Deciduous forest studies.

Elm-maple forest, Urbana, Illinois (the "University Woods").

Weese (1924 *a, b*). 4. vii. 1921–3. vii. 1922. Seasonal changes in soil, herb, and shrub strata with environmental data taken on location. Sweep-net samples (10 sw.) and soil samples (upper 10 cm., 2 sq. ft.). These were taken nearly every week. Complete data presented in graphs and tables for invertebrates, temperature, and evaporating power of air (by Livingston atmometers). Twenty-nine abundant species. Species listed by strata[2] as follows (total 511):

[1] These terms and abbreviations are commonly used by American ecologists to denote the biological seasons of the year, i.e. *Hiemal* = winter, *Prevernal* = early spring, *Vernal* = spring, *Estival* = early summer, *Serotinal* = late summer and *Autumnal* = autumn, *Hibernal* = hibernating. They are arbitrary sections of the seasonal cycle, which cannot be at all rigidly defined. Opinions differ as to the value of employing such rigid distinctions in describing the complex rhythms of animal and plant communities; but an acquaintance with their intended meaning is necessary for any critical appreciation of the literature of this subject. Charles Elton (Ed.).

[2] Here, as elsewhere in this synopsis of papers, these numbers of species represent the species listed by the author. No pretence is made that these numbers represent an approximation to the total number of species present, but are rather an index to those identified and which may be considered *as a minimum*.

Ground species	188
Herb species	201
Shrub species	122

Blake (1926, 1931). 6. x. 1924–15. vi. 1925. Sweep-net samples (10 sw.) and soil samples (2 sq. ft.). Complete environmental data; summarized total population data (in numbers of individuals), with discussion and details for more abundant species only; notes on bird censuses.

Smith (1928), Davidson (1930, 1932). v. 1925–ix. 1926. Sweep-net samples (50 sw.), soil samples (1 sq. ft. in leaf and top soil (10 cm.) strata). Seasonal fluctuation and succession from barren areas to forest; a comparison of the two years studied (1932); animals in tree strata, in summer (1930). Abundant species listed in various stages, by seasonal communities:

	Perennial nucleus	V.	E.	S.	A.
"Pioneer stage"	6	2	6	3	1
"Sweet clover stage"	20	4	8	5	4
"Forest edge stage"	11	6	10	6	7
"Flood plain forest"	7	6	9	10	?
"Elm-maple forest" (Univ. Woods)	25	13	5	12	13

Oak-hickory forests in Missouri and Oklahoma.

Brown (1931). Missouri (St Charles Co., 5 stations), 23. ix. 1926–12. ix. 1927; Oklahoma (Cleveland Co., near Norman, 4 stations), 24. ix. 1927–14. v. 1928. Sweep-net samples (10 single sw.) and soil samples (1 sq. ft., 10 cm.). Meteorological and biotic data on graphs (total populations in individuals and for abundant species only). Abundant species listed:

	Perennial nucleus	H.	V.	E.	S.	A.
Missouri	10	20	18	4	1	20
Oklahoma	6	7	6	8	7	21

Forest edge of the University Woods, Urbana, Illinois.

Carpenter (1934 *b*, 1935 *b*). Also forest interior data, unpublished (1934 *b*). 10. vii. 1932–14. v. 1933. Sweep-net samples (50 sw.) and soil samples (1 sq. ft.). Abundant species: Perennial nucleus, 15; P. 10; V, 6; E. 16; S. 8; A. 6; H. 2; Hibernal, 6.

Wooded ravine (elm-cottonwood) in prairie area, McClain Co., Oklahoma, near Norman.

Carpenter (1936 *c*). 26. ix. 1933–4. v. 1935. Sweep-net samples (100 sw.). Seasonal changes and succession. Abundant species (among Coleoptera, Homoptera, Hemiptera, and ants only): H. 5; Hibernal, 20; P. 16; V. 14; E. 14; S. 11; A. 19.

Successional stages on a flood plain near Norman, Oklahoma.

Hefley (1936). 30. ix. 1933–10. x. 1934. Seasonal changes and ecological succession. Sweep-net samples (100 sw.). Abundant species (insects only) in following stages:

Salix-Populus-Poa	70
Tamarix	43
Salix-Populus-Polygonum-Paralimna-Napaea	78
Salix-Populus	49
Populus-Salix-Cicadella-Haltica	63
Edaphic subclimax prairie	55
Cottonwood subclimax parkland	45
Cottonwood dune parkland subclimax	50
Edaphic elm-oak forest	58

Prairie.

Prairie in south-west Oklahoma (Wichita National Forest Preserve).

Weese (in Taylor *et al.* 1935). 6. vi. 1928–3. vii. 1928. Sweep-net samples (50 sw.). A comparison of insect populations in overgrazed and normally grazed prairie. 782,000 individuals (average) on over-grazed and 186,000 individuals per acre on normally grazed areas.

Prairie in east central Illinois (west of Champaign).

Shackleford (1929). Seasonal fluctuations in high prairie, subclimax high prairie, and low prairie (three stations in each). Sweep-net samples (50 sw.) and ground samples (½ sq. ft.). Number of insect species listed, by communities:

	Perennial nucleus	H.	P.	V.	E.	A.
High prairie	17	8	16	13	45	26
Subclimax high prairie	2	2	3	12	27	15
Low prairie	3	2	2	16	18	12
Low prairie with willows	5	4	2	10	22	19

Rice (1932). 12. iii. 1928–24. v. 1928; 4. iii. 1929–i. v. 1929. Sweep-net samples (50 sw.) and soil samples ($\frac{1}{10}$ sq. m.). Effect of burning on high prairie. About 70 species both on burned and unburned areas but in different abundances. Total populations given, analysed into general taxonomic groups.

Prairie in central Oklahoma, near Chickasha.

Smith & Shackleford (1928), Davidson & Shackleford (1929), Shackleford (1935). (1928): 26. ix. 1927–30. xi. 1927; (1929): 13. iv. 1928–2. v. 1928; (1935): 12. xi. 1933–5. xi. 1934. Seasonal fluctuations. Sweep-net samples (50 sw.), soil samples (½ sq. ft.). (1928): Some data: average total populations for October (122) and first two weeks of November (130); data presented in terms of percentage composition of total populations. (1929): herbs, 54 species identified and listed; ground, 17 species; stratal distribution of ground population given. (1935): among Coleoptera, Arachnids, and Collembola, 8, 4, and 3 species are given (respectively) for ground stratum, and 6, 1, and 2 respectively for Coleoptera, Arachnids, and Hemiptera in herb stratum.

Prairie studied by Shackleford (1929).

Eight prairie types in Iowa.

Hendrickson (1930–31). 1925–28. No quantitative data, but excellent lists of commoner species (about one-half the total collected) by communities. Total species in all habitats: 1175. The "common and more numerous" species listed by orders and habitats are shown below:

Community	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Total
Bouteloua hirsuta-B. curtipendula	8	6	3	7	1	3	—	28
Andropogon scoparius-Bouteloua curtipendula	16	15	22	11	6	5	1	76
Stipa spartea-Andropogon scoparius	10	25	17	27	17	16	8	120
Andropogon furcatus-Sorghastrum nutans	6	13	11	21	6	2	5	64
Andropogon furcatus	18	16	15	33	21	11	10	124
Spartina	12	19	4	28	37	9	7	116
Carex	—	—	1	5	10	—	—	16
Polygonum (smartweed)	—	5	2	13	10	—	2	32

(1) Orthoptera, (2) Hemiptera, (3) Homoptera, (4) Coleoptera, (5) Diptera, (6) Hymenoptera, (7) Lepidoptera.

Prairie in McClain Co., Oklahoma, near Norman.

Carpenter (1936*b*). 26. ix. 1933–4. v. 1935. Seasonal fluctuations and effect of burning. Sweep-net samples (100 sw.). Abundant species among Coleoptera, Hemiptera, Homoptera, Orthoptera, and ants only number:

	Perennial nucleus	H.	P.	V.	E.	S.	A.
High prairie	3	—	2	18	19	17	12
Sloping prairie	3	2	7	26	21	17	12
Low prairie	1	3	6	13	22	8	19
Burned high prairie	1	—	0	13	25	10	8
Burned sloping prairie	1	1	2	16	23	15	11

Coniferous forest.

White pine-hemlock forest, Mt Katahdin (Orono Co.), Maine.

Blake (1926). 7. vii. 1923–25. viii. 1923. Sweep-net samples (10 sw.), soil samples (2 sq. ft.). No figures published; graphs of meteorological records and of total populations by strata and for more abundant species. Abundant species for estival period, by strata: shrub, 5; herb, 7; leaf, 2; soil, 1.

Aspen parkland.

Communities of Aspen parkland near Birtle, Manitoba.

Bird (1930). Succession and seasonal fluctuation of all animal populations. Sweep-net samples (3–5 sw.), soil samples (1 sq. dm.). Number of invertebrate species (annelids, molluscs, and arthropods): Prairie, 136; *Salix petiolaris* station, 218; *Salix longifolia* station, 144; Mature poplar community, 162.

Miscellaneous communities.

Pine dunes near Chicago, Illinois.

Sanders & Shelford (1922). Summer, 1914. Change during summer months and diel differences. Sweep-net samples (4 sw.), soil samples (by means of inverted bucket, 25 sq. cm.). Species: ground, 10; herbs, 34; shrubs, 38; trees, 11.

Tropical jungle near Para, Brazil.

Beebe (1916). 1915 ? A single sample of soil debris. Percentage of total population by orders given for this sample and a similar sample from a field in the New York Zoological Park.

Two city lots in Champaign, Illinois (originally a prairie area).

Wolcott (1918). 25. ix. 1916–18. v. 1917. Soil samples by inverted bucket (0·518 sq. ft.). Complete data presented by orders; no species given.

River flood plain near Perm, U.S.S.R.

Beklemischev (1934), Gudoshchikova (1927). 27. vi. 1927–23. x. 1927. Sweep-net samples (4 samples of 25 sw. each). Diel and seasonal changes. Graphs and tables by orders; a few species discussed.

C. Conclusions drawn from studies using the sweep-net method

1. *Fluctuations of animal numbers in biotic communities*

Fluctuations in the number of animals active in communities may be divided into three categories: (1) fluctuations from hour to hour within the daily cycle of 24 hours (*diel*); (2) fluctuations from season to season within the yearly cycle (*seasonal* or *aspectional*); and (3) fluctuations from year to year (*annual*). Thus far no "sweep-net" studies have been published dealing with the third type.

Fluctuations in population census figures may be the result of real intra-ennial differences in animal abundance, periodic (diel or seasonal), lateral and vertical migrations into and within the area, and migrations of animals into various places for periods of quiescence (hibernation, estivation, pupation, egg development, "sleep", etc.) in which the *absolute* population of the entire area is not affected. This latter partial removal of animals from active participation in the life and interactions of the community lessens, to some extent, their influence within the community during that time and—incidentally—

often prevents their being taken in the sweep-net samples. Thus, with the exception of such rapidly flying insects as dragon-flies, some grasshoppers, a few diptera, etc., the sample contains animals active in the vegetation stratum at the time.

2. *Types of fluctuation*

The fluctuation pattern—the shape of the graphs depicting the total population numbers of animals during a given period of time—is rather characteristic of the communities concerned and gives an indication of the times at which life in the communities is most abundant and active. The distribution of population maxima in the sweep-net catches throughout the year is intimately bound up with the length of the growing season and the seasonal distribution of the most important weather factors, temperature and rainfall. In prairie and open areas the maximum population of the year usually occurs in a main summer "outburst" of activity; in forests this "outburst" of numbers is likely to be distributed more throughout the year and the population maxima dependent on seasonal migrations, both vertical and horizontal. Hence in the deciduous forest of east central Illinois are found two distinct peaks or maxima: "Prevernal" (May) and "autumnal" (October) (Weese, 1924 *a*, *b*; Davidson, 1932; see Table I and Fig. 1). These maxima are also found in woodlands of Missouri (Brown, 1931) and Oklahoma (Brown, 1931; Hefley, 1936; Carpenter, 1936 *b*, *c*).

Table 1. *Periods of maximum seasonal populations*

Community	Vegetation						Soil						
Season ...	H.	P.	V.	E.	S.	A.	H.	P.	V.	E.	S.	A.	Reference
Elm-maple forest	.	.	X	.	.	X	.	.	.	.	.	X	Weese, 1924, Davidson, 1932
Oak-hickory forest	.	.	X	.	.	.	.	.	.	.	.	.	Brown, 1931
Ecotone prairie (Ill.)	.	.	.	x	.	X	.	.	.	.	x	X	Shackleford, 1929
Climatic prairie (Okla.)	.	.	.	X	x	.	.	X	x	.	.	x	Shackleford, 1935, Carpenter, 1936 *b*
Northern prairie (Man.)	.	.	.	x	x	.	X	.	x	.	.	.	Bird, 1930
Location							Seral stage						
Illinois sere to forest	.	.	.	X	x	.	Pioneer						Davidson, 1932
	.	.	.	X	.	.	Clover						
	.	.	X	.	.	X	Forest edge						
	.	.	X	.	x	.	Flood plain forest						
Oklahoma seres to flood-plain forest and prairie	.	.	X	.	.	x	*Salix*-grasses						Hefley, 1936
	.	.	.	X	.	.	*Tamarix*						
	.	.	.	X	.	x	Early *Salix*						
	.	.	.	x	.	X	Edaphic *prairie*						
	.	.	X	.	.	x	*Populus-Salix*						
	.	x	.	X	.	x	Parkland						
	.	.	X	.	.	X	Elm-oak forest						

Note: X = major population peak; x = minor peak.

In prairie areas the typical curve is essentially unimodal, with the single peak in the "estival" (early summer) period with but a slight decrease during

the "serotinal" (late summer) period; low prairie, however, tends to be a little more bimodal in character with an added autumnal maximum in October (Carpenter, 1936 *b*). This latter type of curve is approached in the subclimax high prairie of such ecotone areas as eastern Illinois; in both high and low prairies in Illinois the autumnal maximum is greater than the estival (Shackleford, 1929) which would appear to be correlated with a similar large maximum in the climatically climax forests there. In the prairie area of Manitoba the population in the vegetation reaches its maximum during mid-July and early

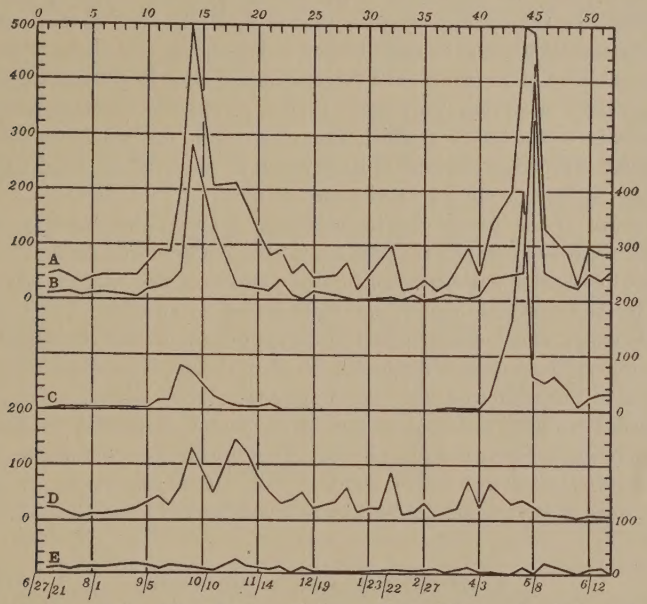

Fig. 1. Animal population data. Total population, and population of the shrub, herb, leaf and ground strata of an area of 4 sq. ft. in the forest. A, Total population; B, population of the herb stratum; C, population of the shrub stratum; D, population of the leaf stratum; E, population of the soil stratum (from Weese, 1924 *a*, by permission).

August, but since the growing season is very short, no insects or other invertebrates are present in the vegetation except during the summer. The ground forms are found to be much more numerous; their maximum is during the winter, with marked decreases during the summer months when the migratory birds are present (Bird, 1930). This agrees essentially with the behaviour of the ground forms in Illinois (Shackleford, 1929). Ground populations in Oklahoma prairie assume a maximum in the spring (Shackleford, 1935); in Illinois woodland the soil population reaches its maximum in late autumn.

That the shape of the seasonal curve of population fluctuation is in part, at least, characteristic of the biotic communities as such and not wholly a result

of the climate locally may be seen on the examination of the curves of the seral studies of Davidson (1932) and Hefley (1936). The former study, dealing with successional stages leading to a deciduous forest climax unfortunately does not include the autumnal period, but the shift of the maxima with the change of the community is significant in the remainder of the year. In Hefley's study a large number of stations was used, but only several representative ones are taken here for comparison (Table 1, lower half).

It will be noted that shift of seasonal maxima is very marked between communities and that widely separated stations placed in similar communities (e.g. prairie in Illinois and edaphic prairie in Oklahoma, climax prairie in Manitoba and Oklahoma, edaphic forests in Oklahoma and climatic forests in Illinois) exhibit similar community fluctuations. This is in accordance with the view expressed elsewhere (Carpenter, 1936 *a*, p. 286) that biotic communities have certain characteristics which are very much the same wherever the community is found, regardless of its position in the local sere, and regardless of whether it may be climax for the area or not.

A review of the papers dealing with diel fluctuations has already been prepared elsewhere (Carpenter, 1936 *a*); in that study it was shown that characteristic fluctuation patterns exist for diel changes as well, and that these may alter with the seasonal change, e.g. from spring to autumn. These changes probably play a very important part in the food-chain interrelationships within a community. The papers of Sanders & Shelford (1922), Gudoshchikova (1927), Davidson & Shackleford (1929) and Carpenter (1935), together with certain unpublished work of Shackleford and of Carpenter show that fluctuation is much more intense between diel phases in late subclimax communities than in the earlier seral or climax stages, and that daily lateral migrations are greatest in such areas of environmental tension as are exhibited in ecotone habitats.

3. *Amplitude in seasonal fluctuations*

The degree or intensity of fluctuations in animal numbers may be expressed in terms of their amplitude. Perhaps the simplest way to express amplitude of fluctuation is by noting the maximum and minimum populations present during a given course of time; since in many areas the winter population sinks to approximately nil, the largest number present during the period in question gives an index of the degree or extent of fluctuation. There is, however, a relatively greater degree of error in the sampling of large populations and the exact figure of the maximum should be taken with some caution. The chief value of having some index of the amplitude of fluctuation is in the comparison of data for different areas to ascertain their relative intensities of variation. Table 2 summarizes some data on this subject. In addition to the degree of fluctuation the time of year at which such a fluctuation or maximum occurs is also of importance and has been discussed in the previous section.

Table 2. *The extent of change in total populations throughout the year as illustrated by several community studies. Data in terms of approximate averages of total populations for seasonal societies; numbers in brackets indicate the population at the maximum during the period. When only a maximum is indicated, it was built up gradually and did not consist of an isolated peak*

Study	Number of sweeps	Seasonal society					
		H.	P.	V.	E.	S.	A.
Elm-maple forest (Weese, 1924 *a*, *b*)	10	0–10	40	(450)	70	15	(352) 30
Oak-hickory (Mo.)	10	5	15	100	70	40	40
Oak-hickory (Okla.) (Brown, 1931)	10	10–15	20	(180) 20	50	n.d.	90
Elm-oak (Okla.) (Hefley, 1936)	100	30	(245) 220	(225) 200	60	30	(160) 70
Elm-cottonwood (Okla.) (Carpenter, 1936 *c*)	100	4–10	(110) 90	60	20	10	(80) 35
High prairie (Okla.)	100	0–5	15	(70) 30	(50) 40	30	35
Sloping prairie (Okla.)	100	4	(66) 30	(46) 40	(191) 90	30	45
Low prairie (Okla.) (Carpenter, 1936 *b*)	100	4	(66) 20	(54) 30	(52) 45	(65) 50	— 30
High prairie (Okla.) (Shackleford, 1935)	50	0–10	(233) 75	(228) 200	(308) 175	20 (3)	(269) 175
High prairie (Ill.)	50	0	—	50	(475) 150	30	(814) 50
Low prairie (Ill.) (Shackleford, 1929)	50	0	—	75	(420) 150	30	(520) 50

4. *Structure of communities*

Markedly different communities show striking resemblances to one another in their structure, especially in the food-chains. Blake (1926), Smith (1928) and Carpenter (1934 *a*) call attention to this fact which is illustrated by the actual data of Bird (1929) for the prairie and aspen parkland communities of Manitoba. The existence of one general type of community structure among animals has also been stressed by Elton (1927, see 1935). In all the communities thus far studied in detail a fluctuating perennial nucleus has been found whose members are present throughout the year; to this are added the seasonal societies with their shorter periods of activity. Forms present throughout several consecutive seasonal periods usually have their maximum yearly abundance or exhibit certain physiological phenomena (e.g. reproduction) during a characteristic season.

5. *Distribution of populations*

Generally speaking, the population may be said to be greatest in areas having the greatest amount of exposed leaf surface; hence subclimax areas to forest tend to have much greater populations than does the climax forest because of the decreased number of shrubs and small trees in the latter

(Carpenter, 1935 *b*). Within a given more or less uniform stratum the population may be considered more or less uniform throughout its extent, especially when ecologically equivalent species which may supplant each other locally are recognized.

(*a*) *Population distribution and the influence of particular factors.*

While the vast majority of community phenomena must be recognized to be the result of the interaction of many factors, frequently a single factor may be found to be the controlling one locally. For example, regarding the function of the microclimate it may be said that different communities are characterized by different migrations in this respect; Sanders and Shelford (1922) found the active animal population directly proportional in size to the evaporating power of the air; in Weese's study (1924 *a* and *b*) the reverse relationship was found.

Burning. Rice (1932), working in the Illinois prairie area studied by Shackleford (1929), concluded that early spring burning of prairie areas had an influence, at the time of the prevernal aspect only, the animals appearing to be normal later in the year. It was noted that repeated burning may introduce herbs which partially replace the grasses with a corresponding change of insects. This phenomenon in the more humid portion of North American prairie is in direct contrast to the observations of Carpenter (1936 *b*) in the drier portions. Here it was found that there was practically no prevernal activity at all after early spring burning. The vernal period lasted somewhat longer than the unburned areas, but the remainder of the year was normal as regards the time of the seasonal periods. The population lost many normal prairie species, however, and received a replacement of an approximately equal number of new species, the total population (both in species and individuals) remaining about the same.

Grazing. Weese (in Taylor *et al.* 1935) found that the population of insects in heavily grazed mixed prairie in south-west Oklahoma had more than four times as many individuals as did the normally grazed grassland adjoining. Increases were in the following percentages in the several insect groups: Orthoptera, 900%; Hymenoptera, 400%; Homoptera, 400%; Hemiptera, 1200%; Diptera, a slight increase; Coleoptera, 200%.

(*b*) *Population distribution in associations within a formation.*

Populations may differ in the different associations of a formation; for example, Brown (1931, p. 256) notes that Missouri forests (mixed elm and oak-hickory) have a greater population, both as regards species and individuals, than the oak-hickory forests of Oklahoma. The Illinois forests of Weese, Smith, Davidson, and others, contain a much greater population than the climax beech-maple forests of Indiana (personal observation). (In this discussion, any variation from year to year is not taken into consideration, but in general these statements will obtain.)

(*c*) *Zonal distribution and the relation of communities with local environmental complexes.*

While the community may be considered as a self-contained unit in nature, it certainly is not immune from the effects—biotic and physical—of the other communities which may be close by. It is from this realization that the concept of "local environmental complexes" has developed (Carpenter, 1936 *a*). The idea is well illustrated in such studies of several adjoining communities as have been done by Shelford (1913), Adams (1915), Fletcher (1930), Hefley (1936) and Carpenter (1936 *b*). Brown (1931) finds that the fauna of the forests of Oklahoma has a much closer similarity to the prairie forms than that of similar habitats in Missouri and Illinois. Certain communities, notably seral stages composed largely of exotic plants (e.g. the *Tamarix* stage of Hefley (1936), and the Indian corn plant of Forbes (1915)) may have a fauna distinct from the neighbouring communities. Closely correlated with the item of environmental complexes is that of exposure differences, as found along forest borders. This has received but little attention from the animal standpoint. The author has worked out the influence of exposure differences on birds (Carpenter, 1935 *b*) and in a concurrent study (unpublished) the effect on hibernating quarters of insects. As regards the latter, no essential difference was found at this period of the year since at the time when forms went into hibernation quarters the microclimate in all exposures was essentially similar, the exposure differences of the winter (cold, winds, etc.) not coming until after most movement had ceased. In the spring, however, the south and east exposures in Illinois experienced earliest activity and it was here that the largest number of birds was found. It is extremely possible, therefore, that these two exposures suffered a greater depletion from birds than those in the west and north. After all forms had come out of hibernation the populations were found to be essentially similar. The more rigorous winter conditions in the later emerging exposures may be an explanation here.

(*d*) *Stratal distribution.*

The soil populations of Manitoba have been characterized (Bird, 1930, p. 425) by having marked stratal distribution. Above the surface debris the population is small compared with the soil and debris layers. The latter is usually much greater than the soil itself. The identity of the tree strata as distinct from the upper shrubs in the forest has been pointed out by Davidson (1930) (see also Townsend, 1928).

(*e*) *Seasonal distribution.*

The seasons usually recognized in aspectional work are the Prevernal (early spring), Vernal (spring), Estival = Aestival (summer), Serotinal (late summer), Autumnal, and Hiemal (winter). (These names have been applied to avoid the confusion which usually results from scientific employment of terms having

loose vernacular meanings when exact meanings are desired.) Inasmuch as many forms, including most of the vegetation, are in a state of "hibernation" during the hiemal period a distinction may be made between the Hibernal (hibernating) society (of organisms in a quiescent physiological state) and the active winter organisms (Hiemal society); where the latter is composed of animals alone (as in northern latitudes) it may properly be termed a presociety in the sense in which that term was originally used (Smith, 1928; Shackleford, 1929), since the animals are then functioning in a community quite different from the plants. The presence or absence of a hibernal group as distinct from a hiemal one is, as far as many invertebrates are concerned, dependent on the local climatic conditions, which are, in turn, chiefly dependent on altitude and latitude. Low thresholds of activity of many invertebrates allow them to become active during the warmer days which raise the temperature above their threshold points. These occasions will be much more frequent in southern latitudes and much less frequent in the northern latitudes (in the northern hemisphere). The mammals and winter birds, of course, fall into the hiemal group, except, of course, those mammals which hibernate.

The identity and integrity of the seasonal society have been especially remarked upon by Shackleford (1929, 1935) who notes that the life histories of organisms are so regulated to have their abundant period fall distinctly into a particular society. An interesting fact has been noticed by Davidson (1932, p. 310) in regard to the seasonal abundance of individual species: 11 forest species shifted their time of seasonal activity to a later seasonal period (e.g. estival to serotinal) and seven *vice versa* in the two years (1925, 1926) studied by her. There is probably a relation here between the retarding and acceleration of seasonal life histories and the perennial cycles; a comparable phenomenon is to be found in the change of time in daily activity at different parts of the seasonal cycle.

Weese (1924 *a*) noted, and the phenomenon has been confirmed by subsequent workers, that migration-movement of seasonal forms into the forest takes place in the following manner: animals move into the forest from the surrounding more open communities during the autumn at the general strata of their summer occurrence and, after reaching the general area of the hibernation quarters, move downward to the strata of winter occupation. In the spring the reverse occurs, animals being late in going into hibernation frequently being the first to emerge in the spring. The trend upward in the spring has been examined in detail (Carpenter, 1934 *a*) and the movement of the animal population is found to correspond closely with a similar stratal trend in leaf development on the part of the plants: ground plants are most characteristic of the prevernal period. Next to come into leaf are the shrubs and short trees, while the dominant trees are in the reproductive state; finally the forest crown comes into leaf and the prevernal period is at an end. There seems to be some tendency for species living in the forest edge to move into

the forest interior and those outside to remain in the forest edge during the winter, but it was not found to be a universal rule. This phenomenon of seasonal lateral migration was found to be less extensive into the Missouri forests and very small in Oklahoma (Brown, 1931). In the moister habitats in the latter area, however, this migration does occur (Hefley, 1936; Carpenter, 1936 *b*). Vertical seasonal migrations have been studied by Townsend (1928) in an artificial deciduous grove in Illinois; but the study was not conducted by means of the sweep-net method (screen fly traps were used).

Movement in winter was noted by Blake (1926) to consist of vertical migrations within the soil and duff strata with major microclimatic fluctuations. When movement did occur it usually resulted in comparatively large distances (e.g. 10 cm.), and not merely from the leaf stratum to the upper soil.

(*f*) *Population distribution in diurnation.*

The literature of fluctuations within the diel period (i.e. within the period of 24 hours) has been reviewed elsewhere (Carpenter, 1936 *d*).

(*g*) *Population distribution during succession.*

Davidson (1932) draws the following conclusion about populations in seral successions: the populations of seral stages as indicated by the mean weekly catches from each stage continually increase from the pioneer to the climax stage, with a mean relative variability which is approximately constant. The number of seasonal and incidental species decreases as succession proceeds, and is least in the climax; the reverse is true of perennial predominants. An analysis of unpublished work by Shackleford and Smith-Davidson for a sere in the state of Washington, and the work of the author has shown that in certain seres the population reaches its maximum just before the climax stage is reached and that it is here that the maximum variability occurs in seasonal and diel differences (Carpenter, 1936 *d*, see Fig. 1).

D. Summary and conclusions

1. The literature dealing with quantitative sampling of land animal communities by means of the sweep net, is reviewed. Reference is also made to certain unpublished work, some of which is available for consultation at institutions in the United States.

2. Although statistically, and from the standpoint of complete survey, the method of sweeping may leave certain things to be desired, the method has certainly enabled several principles of community ecology to be discovered.

3. Communities in various different types of vegetation (forest, prairie, etc.) show characteristic seasonal fluctuations. The general agreement between the results of different surveys is one of the strongest arguments for the employment of the sweep-net sampling method.

4. Different types of habitat, and different stages in succession have characteristically shaped population curves. Some of the factors affecting seasonal aspects of the communities are discussed.

5. In this survey, phenomena have been treated from the standpoint of the animals only (invertebrates, mainly studied in terms of the total population of all species), with the mention of plants and the other animals as part of the environment. The fact that each of the community functions described is a biotic community function should not be overlooked. Each is a resultant and an expression of the sum total of the entire animal and plant community and of the inanimate environment acting together. A study by analysis which does not again integrate is one but partly completed. The sweep-net method may be regarded as a tool that is being tested for use in more complete syntheses.

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A CENSUS OF GANNETS ON AILSA CRAIG, WITH A NEW METHOD OF ESTIMATING BREEDING-CLIFF POPULATIONS

By H. G. VEVERS and JAMES FISHER

(*With Plate* 5 *and* 1 *Figure in the Text*)

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1. Introduction

The recent survey (**2**) of the breeding population of the gannet (*Sula bassana* (L.)) throughout the world has raised many interesting points. With a few exceptions, the numbers quoted were based on estimates rather than on direct counts.

Wiglesworth (**9**) gave a figure for St Kilda, namely 15,000 nests, based on a sample count of 1400 eggs taken from the top of Stac Lii. Wynne Edwards, Lockley & Salmon (**2**) estimate the numbers on Sula Sgeir by the following method. They say that Wontner-Smith and Lockley found it possible to catch and ring nestlings from only 40 % of the nests on Grassholm. Since the ground on Sula Sgeir is similar they think that here it would be possible to kill young gannets from only 40 % of the nests. Quoting then Stewart's (**8**) figure for 2000 young gannets killed by men from Lewis, they compute the total as 5000 occupied nests. This ingenious method probably contains many sources of error.

The method used by the Duchess of Bedford (**1**) on Sule Stack was to make a partial count and deduce the total. In Iceland, Roberts (**6**) visited the four islands of the Vestmannaeyjar colonies in August 1932. His method was to count all the adult birds on the rock. He arbitrarily allowed (*a*) for those cases when the birds were both on the nest, and (*b*) for those cases where pairs of birds were away fishing. Lockley & Salmon (**4**) showed the disadvantages of his methods, and pointed out that he made no allowance for non-breeding birds.

Photo. H. G. Vevers

The Cairn, Ailsa Craig.

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Of the larger breeding stations only two, the Bass Rock and Grassholm, have been counted directly, the first by accurate counts of nests (**5**), and the second by photographic methods. Working independently, Salmon & Lockley (**7**) took photographs covering the whole colony from various different viewpoints; the results of their counts from these photographs were found to approximate very closely. The photographic method was thus vindicated. They estimated from their photographs that on 7 % of the nests both members of the pair were present at one time. They found it impracticable to *count* the number of non-breeders, but were able to estimate them. Beside the photographic method their main contribution to the problem seems to be the emphasis they place on basing such a count on the number of breeding *pairs*.

Gurney (**3**) computed the number of gannets on Ailsa Craig by this method. A photograph taken from a projecting part of the cliff showed 855 "white specks", the greater part of which were "undoubtedly gannets". He considered this to be a sixth part of the whole breeding area. He then suggested that 750 of the white specks were really gannets. He then reckoned that an arbitrary 350 had mates away fishing. From these various hypotheses he deduced the size of the community to be 6600 gannets.

Wynne-Edwards, Lockley & Salmon (**2**) point out that even on his own datum Gurney's amended figure of 6500 is too low. Salmon (**9**), assisted by Lord Dumfries, in 1935 estimated the population of the Craig to be about 7500 pairs.

2. Methods attempted

Our investigation lasted from 7 to 16 April 1936, and we visited some part of the bird cliffs at least twice a day. We tried two methods of counting and one of estimation.

(*a*) *Method of direct counts*

The time of year was particularly suitable for this method, as at least one of the pair was always at the nest. A small source of error is the possibility that not all the birds which hold nesting sites are necessarily mated. The cliffs were divided into sections according to their local names, and the section divided up where possible according to the groups of gannets. Only one large group (the Mare) was impossible to split. Each group was counted with field-glasses, often more than once and on different days. We counted separately but simultaneously. Where we could avoid "dead ground" we did this from the beach, otherwise almost entirely from a boat, when calm, or in two cases (Balvaar and the Barrheads) from the top of the cliffs.

Our results are tabulated below. When figures are bracketed together the count has been repeated, and the mean of the two counts used towards the total. Our totals tallied very closely, the difference being 0·51 %. This was a count of the number of nests, and did not include non-breeders. Like Salmon

& Lockley (7) we can only rely on an estimate for the latter, and we tentatively suggest 500.

These figures can all be referred to the groups on the map.

Cliff	J. F.	H. G. V.
Barestack		
B 1	29 30	30 29
B 2	7	7
B 3	10	11
B 4	5	5
B 5	20	23
B 6, etc.	19	19
Northwards of Ashydoo		
North part	152 143	139 141
South part	128	129
Ashydoo		
A 1	212	211
A 2	48	46
Balvaar	228	228
Barrheads		
North	131	133
Mid-group	9	9
South	19	19
Between Balvaar and the Cairn	64	63
The Cairn	618 585	603
Between the Cairn and the Mare	385	373
The Mare		
North	550	575
South	970	995
Lower ledge	39	38
Between the Mare and Stranny Point		
S 1	100	103
S 2	69	66
S 3	113 120	111 115
S 4	210	221
Main Craigs		
Top ridge	94	94
Main part	433	426
East	104	103
Far East	33	35 33
Totals*	4782	4816·5

* Giving mean number of nests 4799·25, i.e. 4800 in round numbers.

The figures in brackets are duplicate counts.

We conclude that the total number of gannets on Ailsa Craig was $4800 \times 2 = 9600$, plus non-breeders estimated at 500—a final figure of slightly over 10,000.

(*b*) *Photographic method*

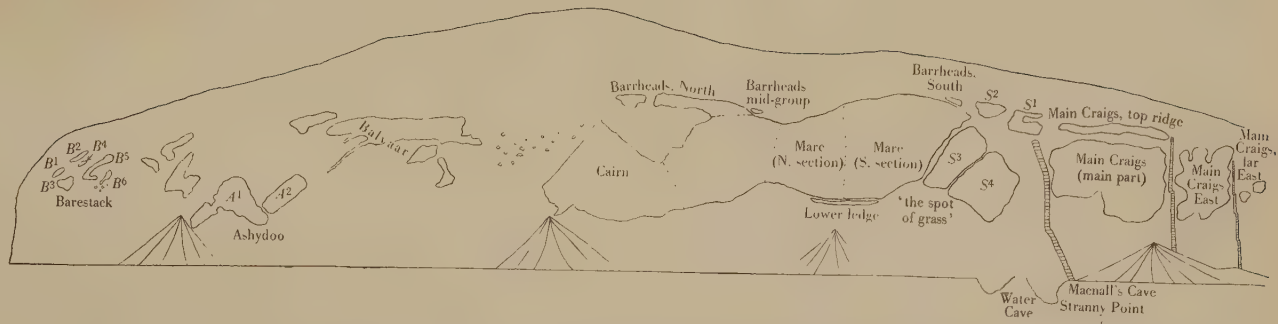
Photographs were taken of most of the cliffs under ideal conditions, from the boat, but when close in the amount of dead ground was too much, and when far out the definition was lost. A photograph of the Cairn was also taken from the Barrheads. Gurney's photograph (3) was probably taken from much the same place as ours.

The photographic method used on Grassholm (7) is impracticable on Ailsa Craig.

(*c*) *Estimation by the alighting method*

On the Main Craigs, East, there were 103–104 nests, on the Main Craigs, Main part, 426–433. The number of birds that alighted on each of these in 5 min. was counted.

	No. of nests counted	No. of birds alighting
Main Craig, East	103–104	10
Main Craig, Main part	426–433	37



Panorama diagram of the west cliffs, for a distance of a mile and a quarter from Barestack in the north to the Main Craigs in the south, showing the system of natural and artificial divisions used in counting gannets.

Natural boundaries of colonies.

Dolerite dykes.

Artificial divisions for counting.

Talus slopes.

These counts were made simultaneously, and the ratios show a difference of no more than 10%. This then, though subject to error in small numbers, suggests a method of estimation of large colonies of cliff-dwelling birds. A control area is counted and the number of birds alighting timed over a given interval. The numbers alighting on other portions of the cliff are likewise counted. Care must be taken that no change in the activity of the birds takes place in the meanwhile.

For example, using the Main Craigs, Main part, as a control for an estimate of the Mare, our result was:

	No. of nests	No. alighting in 5 min.
Main Craigs, Main part (control)	426–433	35
Mare: 1st 5 min.	?	139
2nd 5 min.	?	118

From this we obtained an estimate of the number of nests on the Mare as 1577. Our actual count was 1559–1598 (mean 1578·5). The close correspondence of these figures is probably a coincidence but it vindicates the method used.

We used this method on the kittiwakes (*Rissa tridactyla tridactyla* (L.)) on the Barestack, with a control group of 200 nests counted directly, and a 5 min. observation.

Group	No. of nests	No. alighting in 5 min.
A (control)	200	13
B	?	10
C	?	17
D	?	12

This gives an estimate of 800 pairs of kittiwakes nesting on the Barestack. It is important that each time the control is used the number alighting on it should be recounted, as the activity of the cliff as a whole probably changes from hour to hour.

While our results with gannet estimation are too few to bear statistical investigation, we claim nevertheless that this method is justifiable for estimating the numbers of large cliff colonies.

3. Acknowledgments

In conclusion our thanks are due to Miss M. L. E. Turner for assistance with counts, and to the Girvan family for help ashore and on the rock.

4. Summary

1. Methods hitherto used in counting and estimating the number of gannets (*Sula bassana* (L.)) on their breeding cliffs are reviewed.

2. A direct count of gannet nests on Ailsa Craig gave about 4800 nests, i.e. 9600 birds, not counting non-breeders estimated roughly at 500.

3. The photographic method of counting was found impracticable on Ailsa Craig.

4. A new method of estimating, by correlating the alighting activities of the birds, is described. This may be applicable, it is hoped to all kinds of breeding cliffs.

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THE POPULATION OF PARTRIDGES (*PERDIX PERDIX*) IN GREAT BRITAIN DURING 1935

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(*With 4 Figures in the Text*)

1. Introduction

The aim of this paper is to continue the records given for 1933 and 1934 in a previous paper (**1**) and show the trend of the partridge population during the last 3 years. This work forms part of a scheme of research on game populations carried out by the Bureau of Animal Population with the aid of a grant from Imperial Chemical Industries.

Most of the statistics used in this paper are derived from counts and records made by keepers and owners of estates under a system developed for this research, the technique of which has already been described (**2**). I wish to thank all those who are collaborating in this work.

The partridge population of most areas in Britain, particularly in the south and east, showed a marked increase during 1933 and 1934 after a period of low numbers and disease in 1931 and 1932. Two favourable summers for the survival of young birds had rapidly built up the stock, so that, in spite of the fairly large numbers shot in 1934, there was in most areas a higher density of nesting birds at the beginning of 1935 than for several years past.

2. Nesting

Table 1 gives the records obtained on the nesting of partridges in 1935 on different estates in Britain. For the estates listed in the first half of this table comparable data have been given for 1934 and (for some) 1933, and it will be seen that most of these show an increase in the number of nests compared with 1934. Table 2 and Fig. 1 show the increase in the number of nests found on 11 estates for which data are available over the past 3 years: these estates are the first 11 listed in Table 1 and in the corresponding table given in the previous paper. The increases shown would undoubtedly have been much greater had it been possible to include in this figure some of the Norfolk estates, as it is certain that the increase during the past 3 years has been more rapid in Norfolk than in any other part of Britain. Indeed, it seems that on some estates in Norfolk the nesting stock approached maximum density in 1935, e.g. on B 13 and T 2, where average densities of one nest to

Table 1. *Records of nesting and hatching of partridges in* 1935

Estate and County		Area in acres	Nests: Estimated total	Nests: Number found	Nests: Number hatched	Nests: % hatched	Eggs and young: Av. clutch size	Eggs and young: Av. brood size	Eggs and young: % eggs hatched
*L 1	Hampshire	1,100	60	47	39	83	—	—	—
W 6	,,	2,000	150	125	113	90	14·5	12·4	86
F 1	Wiltshire	5,000	180	115	81	70	17·5	16·2	93
*C 1	Cambridgeshire	900	140	118	105	89	16·7	16·0	96
S 1	,,	11,000	1,100	1,028	940	91	—	—	—
B 4	Warwickshire	2,700	—	67	58	87	—	—	—
H 1	Worcestershire	1,700	65	22	11	50	14·9	13·8	93
D 2	Northamptonshire	5,000	—	58	38	65	15·2	12·9	85
*B 2	Yorkshire	2,000	110	92	54	59	14·8	13·4	91
L 2	Northumberland	2,000	115	28	24	86	15·3	13·4	87
M 1	,,	830	65	26	17	65	13·4	12·7	95
C 5	Isle of Wight	2,600	150	86	56	65	15·3	12·0	78
M 2	Hampshire	2,700	—	—	77	—	—	—	—
*L 8	Berkshire	1,700	160	125	98	78	—	—	—
C 10	Suffolk	1,600	156	142	108	76	15·4	12·7	82
*W 11	Norfolk	1,400	136	126	121	96	14·8	14·4	97
W 1	,,	3,000	350	305	267	87	16·2	14·6	91
D 4	Lincolnshire	—	—	165	50	30	15·7	11·6	79
A 2	Derbyshire	640	28	13	8	62	13·4	12·8	95
R 2	Hampshire	4,000	—	—	249	—	16·0	15·0	94
L 4	,,	1,150	80	67	62	93	16·2	15·0	93
*H 9	Essex	800	75	70	52	74	—	—	—
W 4	Norfolk	5,000	400	367	326	89	15·8	14·8	94
R 7	,,	3,000	120	99	79	80	14·6	13·7	94
H 5	,,	3,500	395	341	—	—	14·3	13·3	93
T 2	,,	2,700	430	413	358	87	15·5	14·5	93
B 13	,,	3,000	569	517	481	93	16·2	14·8	91
*C 8	,,	—	120	110	80	73	14·6	11·6	80
W 16	,,	3,000	224	204	170	83	—	—	—
W 16*a*	,,	2,000	190	156	143	92	16·4	15·0	92
N 5	Leicestershire	1,200	90	29	23	79	—	—	—
B 14	Oxfordshire	3,000	220	167	125	75	15·4	13·6	88
W 18	Gloucestershire	1,800	110	96	59	62	—	—	—
H 8	Northumberland	4,000	285	125	85	68	15·6	14·1	90
G 2	Kirkcudbrightshire	3,000	250	51	44	86	16·8	15·8	95
D 7	Angus	1,700	230	200	138	69	16·1	14·6	91
D 7*a*	,,	1,500	160	82	69	84	15·9	15·4	97
A 2*a*	Ross-shire	1,500	—	44	30	68	16·2	15·2	93
	Averages	—	—	—	—	77	15·5	14·0	91

* Data for part of the estate—not comparable with bag records.

Table 2. *Partridge nests found on* 11 *estates*, 1933–5

Estate		Area in acres	Nests found: 1933	Nests found: 1934	Nests found: 1935
L 1	Hampshire	1,100	30	47	47
W 6	,,	2,000	77	69	125
F 1	Wiltshire	5,000	100	150	115
C 1	Cambridgeshire	900	37	68	118
S 1	,,	11,000	585	922	1028
B 4	Warwickshire	2,700	38	59	67
H 1	Worcestershire	1,700	16	20	22
D 2	Northamptonshire	5,000	34	41	58
B 2	Yorkshire	2,000	64	79	92
L 2	Northumberland	2,000	30	57	28
M 1	,,	830	25	39	26
	Totals	34,230	1036	1551	1726
	Nests per 1000 acres	—	30	45	50

5·3 acres and 6·3 acres respectively were reached. The former is the highest average density over a large acreage of which I have a record.[1]

The average percentage of nests hatching, 77 %, remains very close to the figure of 78 % obtained in both 1933 and 1934 as well as to the average figure of 78 % shown by more extensive data (**2**). It seems, therefore, that the average loss of nests from all causes on preserved estates remains fairly

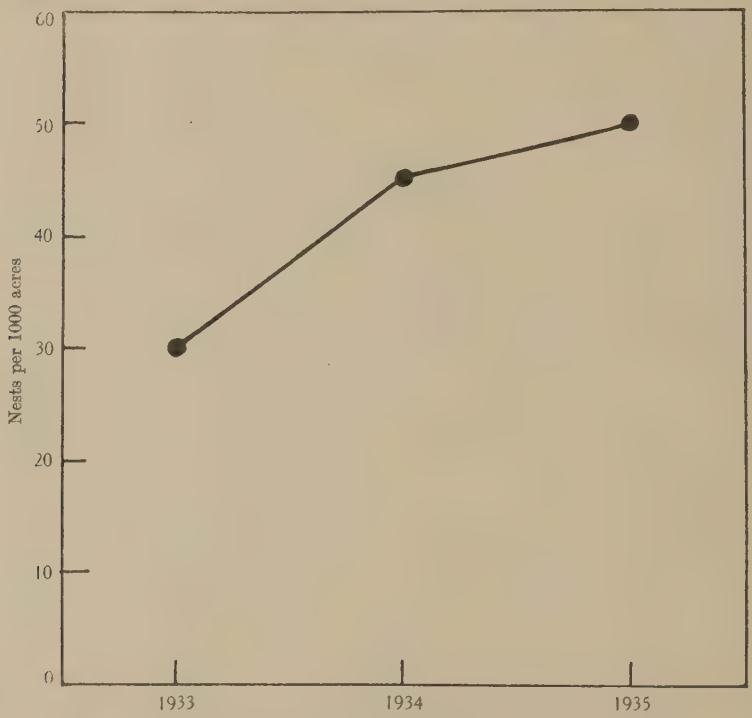

Fig. 1. Partridge nests found per 1000 acres on 11 estates, 1933–5. (Data in Table 2.)

constant at about 22–23 %. This figure does not imply, however, that 22 % of nesting pairs fail to bring off any chicks, as there are a number of second attempts at nesting, after the first nest has been destroyed during the laying period, about which accurate facts are difficult to obtain. The loss of nests indicated is, therefore, the total loss known with no allowance for the success of second attempts. As second nests are frequently situated in growing crops rather than on hedgerows they are not often found.

[1] On the same two estates the nesting density was higher still in 1936, being one nest to 4·5 and 5·3 acres respectively.

The average clutch size in 1935 was slightly higher than in the two previous years, and some estates show an exceptionally high figure. This, in the opinion of many experienced keepers, is due to the fact that a large proportion of the nesting stock was composed of birds hatched in 1934 and the proportion of really old birds must have been very low as a result of 2 years of high production of young ones. It is a reasonable hypothesis to suppose that young females lay more eggs than old ones but I have no accurate data to confirm this. The average clutch shown by records from various estates over periods of several years was 14·6, so the 1935 figure of 15·2 may be regarded as definitely high.

The percentage of eggs hatched (91 %) was slightly below the average shown for a period of years (93 %) (2), but on the whole the nesting season can be classed as a very successful one. The records for the nesting during each of the past three years show very little divergence, all being favourable seasons.

In order to determine the reason for some eggs not hatching after the incubation period is completed a number of "bad" eggs left in partridge nests after the hatch were collected and examined. The following are the results:

Fertile eggs rotten owing to failure to start development or checked during first 3 days	84
Partly developed dead embryo	32
Fully developed, dead in shell	10
Clear eggs, infertile	2
	128

Since, on the average, only 7 % of all incubated eggs fail to hatch it is obvious from the above that the percentage of actually infertile eggs is very low, about 0·1 %.

Table 3 and Fig. 2 show the main hatching period for partridges on two estates in Norfolk. The frequency polygon in Fig. 2 is probably representative of partridges throughout the south of England. Although one often hears it

Table 3. *Dates of hatching of partridge nests on two estates* (W 1 *and* B 13) *in Norfolk*, 1935

Date	No. of nests hatched	%	Date	No. of nests hatched	%
1–3 June	1	0·3	19–21 June	71	22·7
4–6 „	6	1·9	22–24 „	42	13·4
7–9 „	14	4·5	25–27 „	15	4·8
10–12 „	37	11·8	28–30 „	3	1·0
13–15 „	39	12·5	1–3 July	1	0·3
16–18 „	83	26·5	4–6 „	1	0·3

stated that "partridges are hatching early (or late) this year" there seems to be little variation in the peak period of hatching, which is between the 10th and 24th June.

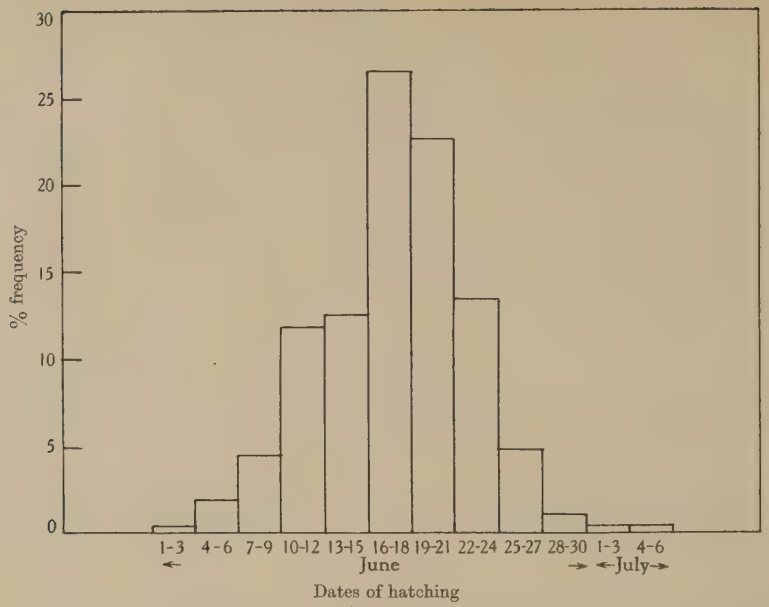

Fig. 2. The percentage frequency of partridge nests hatching on different dates in 1935. (Data from two Norfolk estates in Table 3.)

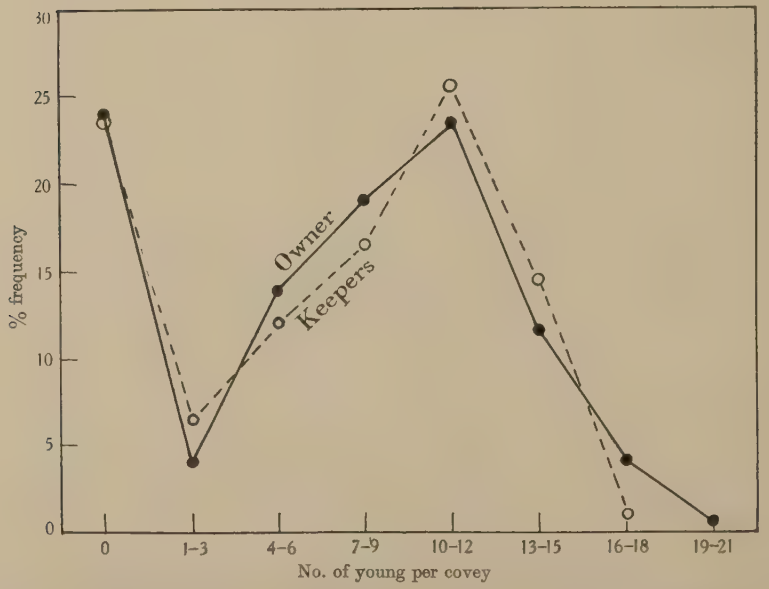

Fig. 3. The percentage frequency of different covey sizes shown by two independent sample counts of partridges on the same estate in August 1935. (See Table 5.)

3. CHICK MORTALITY

Sample counts of young and old partridges were made on a number of estates in the same way as in 1933 and 1934 (**1** and **2**). Data were obtained for most of the estates on which counts were made in 1933 and 1934, and several additional estates are included in the records given in Table 4. On the

Table 4. *Sample counts of old and young partridges made in August* 1935

Estate and County		Counted in August				Young: old ratio	% coveys surviving	Av. young per surviving covey
		Old	Young	Coveys	"Barren"			
L 1	Hampshire	78	112	18	42	1·44	46	6·2
C 1	Cambridgeshire	75	421	32	11	5·61	88	13·2
S 1	,,	527	1006	134	259	1·92	51	7·5
W 1	Norfolk	507	1819	192	123	3·59	76	9·5
D 2	Northamptonshire	106	213	26	54	2·01	49	8·2
O 1	Nottinghamshire	147	405	49	49	2·75	67	8·3
B 2	Yorkshire	78	292	30	18	3·74	77	9·7
S 3	,,	23	26	4	15	1·13	—	—
L 2	Northumberland	136	410	47	42	3·01	69	8·7
R 2	Hampshire	263	481	63	137	1·84	48	7·6
W 6	,,	126	376	44	38	3·00	70	8·6
R 4*a*	,,	97	227	32	33	2·34	66	7·1
R 4*b*	,,	68	138	23	22	2·03	68	6·0
L 4	,,	131	356	44	43	2·73	67	8·1
C 5	Isle of Wight	124	339	50	24	2·74	81	6·8
F 1	,,	121	439	50	21	3·62	83	8·8
L 8	Berkshire	104	376	36	32	3·62	69	10·4
K 1	Hertfordshire	113	151	26	61	1·34	46	5·8
C 10	Suffolk	205	258	35	135	1·26	34	7·4
H 9	Essex	37	78	12	13	2·11	65	6·5
W 4	Norfolk	185	567	54	77	3·05	58	10·5
K 2	,,	50	301	22	6	6·00	88	13·7
W 11	,,	141	683	63	15	4·85	89	10·8
H 5	,,	97	402	40	17	4·14	83	10·0
T 2	,,	142	625	63	16	4·40	89	9·9
D 4	Lincolnshire	159	689	58	43	4·34	73	11·9
W 7	,,	126	377	45	36	3·00	71	8·4
A 2	Derbyshire	35	107	12	11	3·06	69	8·9
M 1	Northumberland	44	141	16	12	3·20	73	8·8
M 2	Hampshire	102	311	36	30	3·05	71	8·6
L 8*a*	Berkshire	85	241	26	33	2·84	61	9·3
S 20	Wiltshire	52	95	13	26	1·82	50	7·3
B 14	Oxfordshire	241	769	88	65	3·20	73	8·7
W 18	Gloucestershire	103	376	41	21	3·65	80	9·2
N 5	Leicestershire	100	226	31	88	2·26	62	7·3
W 16	Norfolk	146	438	53	40	3·00	73	8·3
W 16*a*	,,	230	733	70	90	3·19	61	10·5
B 13	,,	205	722	77	51	3·52	75	9·4
R 7	,,	220	580	65	90	2·64	59	8·9
W 14	,,	65	244	27	11	3·75	83	9·0
H 8	Northumberland	187	344	48	91	1·84	51	7·2
G 2	Kirkcudbrightshire	80	260	—	—	3·25	—	—
D 7	Angus	137	75	15	107	0·55	22	5·0
D 7*a*	,,	153	260	47	59	1·70	61	5·5
A 2*a*	Ross-shire	36	108	14	8	3·60	78	7·7
	Averages	—	—	—	—	3·05	67	8·6

average, the degree of survival of young birds was very similar to that of 1933 and 1934, since all three summers have been warm and dry for the critical period during and immediately after hatching. Storms in Hampshire, the

north of England and Scotland caused a good deal of local mortality but, generally speaking, 1935 must be classed as a season of high productivity. It will be seen that the ratios of young to old are especially high for all the Norfo'k estates, and this resulted in a large stock of partridges at the beginning of the shooting season, especially in the north part of the county where there was a high density of nests.

In order to test the validity of these sample counts when carried out by different observers two independent counts were made over the same ground at Great Witchingham, Norfolk, during the first 10 days of August. One was done by the owner, Mr W. J. Barry, assisted by myself; and another by the three keepers, each keeper making a note of birds seen in the ordinary course of his rounds.[1] The results of these two sample counts are shown in Table 5 and Fig. 3, and would seem to indicate that the data obtained in this way are a reliable index to the production (or mortality) of the young birds.

Table 5. *Comparison of sample counts of old and young partridges made by owner and by keepers independently on the same area, Great Witchingham, Norfolk, August* 1935

	Old	Young	Coveys	Young: old ratio	% coveys surviving	Average young per surviving covey
Owner	507	1819	192	3·59	76	9·5
Keepers	218	799	83	3·65	76	9·6

Number of coveys of different sizes in above samples

Number of young per covey ...	0	1–3	4–6	7–9	10–12	13–15	16–18	19–21
Number of coveys (owner)	61	10	35	48	59	29	10	1
„ (keepers)	26	7	13	18	28	16	1	0
% frequency (owner)	24·1	4·0	13·8	19·0	23·3	11·5	4·0	0·4
„ (keepers)	23·8	6·4	11·9	16·5	25·7	14·7	0·9	—

4. Shooting

As was expected, in view of the increased nesting stock and the general high survival of young birds, the number of partridges available for shooting was considerably greater than in 1934. The total bag for the 43 estates recorded in Table 6 does not, however, show such a great increase over the 1934 total as the increase shown by 1934 over 1933. On these figures the percentage increase in 1934 was 51% over 1933; but the 1935 total is only 9% greater than that for 1934. The high density of nests and low chick mortality rate indicate that far greater kills were possible on many estates than were actually made, and this was certainly true in several instances. The lack of very large totals for the season was probably due in part to the scarcity of adequate cover into which to concentrate the birds for driving. The dry spring and summer of 1935 resulted in a weak growth of the root crops in many areas and without roots it becomes very difficult to drive partridges successfully late in

[1] The keepers each have beats of about 1000 acres: their sample is the total of counts made on various parts of their beats on different days. The owner's sample was made in a series of walks, with two or three helpers, over each of the three beats.

Table 6. *Numbers of partridges killed on different estates in* 1935–6 *shooting season*

Estate and County		Area in acres	Numbers killed 1933	1934	1935
L 4	Hampshire	1,150	189	524	394
M 2	,,	2,700	430	514	613
R 2	,,	4,000	737	1,086	355
C 5	Isle of Wight	2,600	734	624	568
F 1	Wiltshire	5,000	287	354	373
G 5	Hertfordshire	1,200	43	97	88
K 1	,,	1,800	148	207	240
C 1	Cambridgeshire	3,500	335	1,207	2,134
S 1	,,	10,000	1,768	2,398	4,007
H 9	Essex	3,000	470	720	945
C 10	Suffolk	1,600	601	758	506
O 2	,,	11,000	1,789	2,422	2,181
G 6	,,	5,000	1,184	1,702	670
W 1	Norfolk	3,000	337	1,341	2,001
B 13	,,	3,000	701	2,202	2,602
T 2	,,	2,700	1,166	2,113	2,477
H 5	,,	4,000	1,428	2,545	3,921
H 3	,,	17,000	3,469	4,404	5,151
W 4	,,	6,700	803	945	1,376
K 2	,,	3,000	90	335	452
W 11	,,	10,000	910	2,074	2,847
C 8	,,	6,000	543	1,726	2,248
W 14	,,	4,800	741	1,596	1,655
W 16	,,	5,600	868	1,146	1,676
R 7	,,	3,000	184	263	248
L 8	Berkshire	1,700	747	714	850
B 14	Oxfordshire	4,700	868	1,058	746
D 2	Northamptonshire	5,000	581	640	556
H 1	Worcestershire	1,700	150	111	111
W 7	Shropshire	11,000	1,100	1,860	1,519
H 7	,,	2,000	341	550	473
A 2	Derbyshire	640	26	85	43
N 5	Leicestershire	1,200	64	122	176
O 1	Nottinghamshire	5,000	1,786	2,964	2,061
N 1	Yorkshire	2,000	206	269	290
S 3	,,	2,000	335	244	317
B 2	,,	12,000	1,011	899	1,033
H 8	Northumberland	4,000	484	655	256
L 2	,,	2,000	321	392	297
M 1	,,	830	311	206	283
G 2	Kirkcudbrightshire	3,000	432	296	224
W 10	Banff	4,000	869	592	210
B 23	Fife	2,000	568	615	375
	Totals	186,120	30,155	45,575	49,548

the season. It is certain that on many estates in Norfolk many more partridges were left at the end of the shooting season than were necessary for an adequate breeding stock.

Table 7 and Fig. 4 show the trend of numbers killed for a group of estates in Norfolk since 1924, when the population was at a high peak. The last three years of high production have brought the number killed very rapidly up to a figure slightly higher than that of 1930 (the last peak), and, since the breeding stock for 1936 is very large, a successful breeding season would create a very high density by the autumn of 1936. From the graphs of partridge production and sunshine (2), however, it seems unlikely that 1936 will be a good pro-

Table 7. *Numbers of partridges killed on five estates in Norfolk*, 1924–35

Estate	Acreage	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
W 1	3,000	2,063	755	635	69	1,272	1,517	3,540	727	554	337	1,341	2,001
B 13	3,000	2,296	1,915	940	38	575	1,798	1,448	724	829	801	2,182	2,602
H 3	17,000	8,527	2,874	4,279	447	3,306	4,434	4,462	2,125	1,247	3,469	4,404	5,151
H 5	4,000	3,342	1,711	1,897	296	934	2,407	2,709	1,764	545	1,428	2,545	3,921
T 2	2,200	2,127	1,171	1,150	347	797	1,166	2,076	1,209	165	916	1,520	1,772
Totals	29,200	18,355	8,426	8,901	1,197	6,884	11,322	14,235	6,549	3,340	6,951	11,992	15,447
per 1000 acres		628	288	305	41	236	388	487	224	114	238	410	529

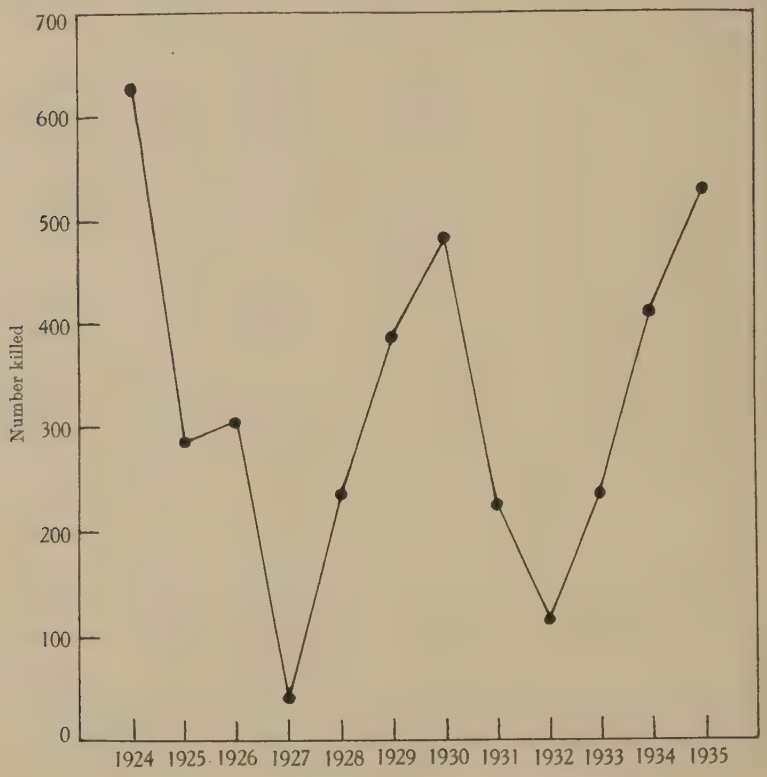

Fig. 4. Number of partridges killed per 1000 acres on five estates in Norfolk, from 1924 to 1935. (Data in Table 7.)

duction year. Although at the time of writing (July 1936) accurate records are not available, general observation indicates that the heavy rainfalls and lack of sunshine during June and July have been the cause of a great deal of mortality among young partridges over most of England, so it seems unlikely that the curve in Fig. 4 will continue to rise so precipitously.

5. Summary

In 1935 the partridge population of most parts of Great Britain showed a further increase. The nesting stock was greater than in 1934, in some areas, e.g. Norfolk, apparently approaching a maximum. A third favourable summer for survival of young, similar to those of 1933 and 1934, resulted in a high autumn density, the numbers killed in 1935 being 9 % greater than in 1934 and 64 % greater than in 1933.

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POPULATIONS AND TERRITORIES OF THE ANTS, *FORMICA FUSCA*, *ACANTHOMYOPS FLAVUS*, AND *MYRMICA RUGINODIS*, AT THORNHILL (YORKS)

By WALTER PICKLES

(*With Plate* 6 *and* 1 *Figure in the Text*)

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1. Introduction

The survey here recorded was undertaken as a further contribution to the records of ant territory (**1**, **2**), and also to determine by actual counts the populations, including the immature forms, of the ants' nests. My previous survey (**2**) was on an area which was level, surrounded by young trees, and had a thick growth of willow herb (*Epilobium angustifolium*) on which Aphides were being cultivated by the ants. The area on which the present survey was carried out was in marked contrast to that one.

2. Nature of area under observation

The area of ground selected for carrying out the survey is situated on a S.S.E. slope of one of the foothills of the Pennine Chain, near Dewsbury, and known as Thornhill Edge. The slope of the ground is very steep, having an average gradient of 1 in 2 on the area selected. This happens to be the steepest part of the hillside.

The vegetation consists chiefly of a very thick growth of bracken (*Pteris aquilina*) with odd patches of brown knapweed (*Centaurea Jacea*) and gorse (*Ulex europaeus*). Intertwining amongst the bracken are the stems of the bramble (*Rubus fruticosus*). Owing to this thick growth of bracken, the ants'

nests were hidden, except those of *Acanthomyops flavus* whose mounds were conspicuous, especially that of nest 1.

In this area 14 nests were observed and marked; 2 of *Acanthomyops* (*Chthonolasius*) *flavus* F., 5 of *Formica fusca* L., and 5 of *Myrmica ruginodis* Nyl. Besides these, two mixed nests occurred: one, *Formica fusca-ruginodis* and the other one *Acanthomyops flavus-ruginodis*. Of these nests 3 were temporary ones, namely, Nos. 4 and 5 (*M. ruginodis*) and No. 7 (*flavus-ruginodis*).

The identification of the ants was kindly verified for me by Mr H. St J. K. Donisthorpe.

3. TYPES OF NESTS

As previously mentioned, the area was dominated by nest-mound No. 1 (*Acanthomyops flavus*). During the winter months, when all the bracken was dead, this nest was very noticeable. However, in summer the bracken growing as tall as, and in some places much taller than, the height of this nest, the nest showed up less. The dimensions of nest 1 are:

Diameter (nest roughly circular)	...	4 ft.
Height (from surrounding ground)	...	1·66 ft.

The nest, however, extended to a depth of 1·25 ft. below the general level of the ground.

All the other nests, except Nos. 2 and 3 (*fusca-ruginodis* and *Acanthomyops flavus* respectively), were made under stones. The nests of *Formica fusca* were all small and not very deep (0·33–0·5 ft.). Those of *Myrmica ruginodis* were often fairly deep, extending to 1·75 ft.

The whole hillside is made up of loose flat stones interspersed with sandy soil; these have been utilized as covers for the nests. The mounds of nests 1, 2, and 3 have been constructed with these stones as their bases. The soil composing the mounds of the *Acanthomyops flavus* nests when dry does not allow the rain to percolate through. I found that after heavy thunder showers only a thin layer of the soil was moistened; this was found to be the case even after the winter rains commencing in September. This ant notably builds its nest to avoid wet, but here a high mound is not necessary owing to the splendid natural drainage. Possibly the fact of the fine sandy soil holding the heat of the sun caused the extra building to occur, as the mound of nest 3 was hardly noticeable and the soil was much coarser. The temperature on the mound was considerably higher than that further down, as shown by observations in August 1935:

Date (August 1935)	Surface temperature °C.	Temp. 8 in. deep °C.
6	35	20
8	43·3	18·8
13	41·1	16·6
15	26·6	15·5

4. Territory

(*a*) *Acanthomyops flavus*

This species of ant does not forage for its food (**3**) and never leaves the nest mound. The ants only seem to come to the surface after a rain shower when they immediately begin to add to the nest mound. They bring up soil from the inside and "tip" it round the openings or mouths of the nest. After a rain storm the openings were very conspicuous owing to these rings of earth. As these ants do not leave the nest mound, it can be safely said that they have no territory, I have never seen one travel any further than the edge of the nest mound.

(*b*) *Formica fusca*

Five nests and a mixed *fusca-ruginodis* nest were located. This species forages in all directions. Almost all the observations of this species were made on ants from nest 2.

The greatest distance to which any of these ants travelled from the nest was 26 ft. As the activity and foraging occurs generally and in all directions we can take the territory covered as being the area of ground covered by a circle with the nest as centre and 26 ft. as its radius: an area of 2124 sq. ft.

Although quick and active, these ants (*Formica fusca*) show their unwarlike nature when meeting with *Myrmica ruginodis*. On encountering one of the latter ants, the *Formica fusca* has on many occasions been seen rapidly to turn tail. In the case of the mixed *F. fusca-ruginodis* nest, the two species although under one mound occupied distinct parts of it, without any intermingling.

The crawling of all the species of ants was greatly hindered by the thick growth of vegetation.

(*c*) *Myrmica ruginodis*

This species of ant was represented by three nests and the mixed *fusca-ruginodis* nest 2. These were permanent nests; but three temporary nests occurred, Nos. 4 and 5 and the mixed *ruginodis-flavus* nest 7. The last was located and found active on 29 August 1935, but had completely vanished by 21 September 1935.

The history of nests 4 and 5 leads me to the conclusion that they were attempts by the same group of ants to found a new nest, most probably coming originally from nest 2.

Nest 4 was the first to be founded, and existed from 13 August 1935 to 26 August 1935, by which time no ants were to be seen under the stone which covered the nest. On this date (26 August) I discovered under a stone 1·5 ft. away from nest 4 a flourishing colony of the same species. As this stone had been lifted up and the underneath examined on several previous occasions (the last time being only a few days earlier) without finding any ants, I concluded

General view of the area, looking S.W. The steep hillside is covered with a dense growth of bracken (*Pteris aquilina*). Nest 1 (*Acanthomyops flavus*) is in the grassy patch in centre of picture.

PICKLES—ANTS

Face p. 264

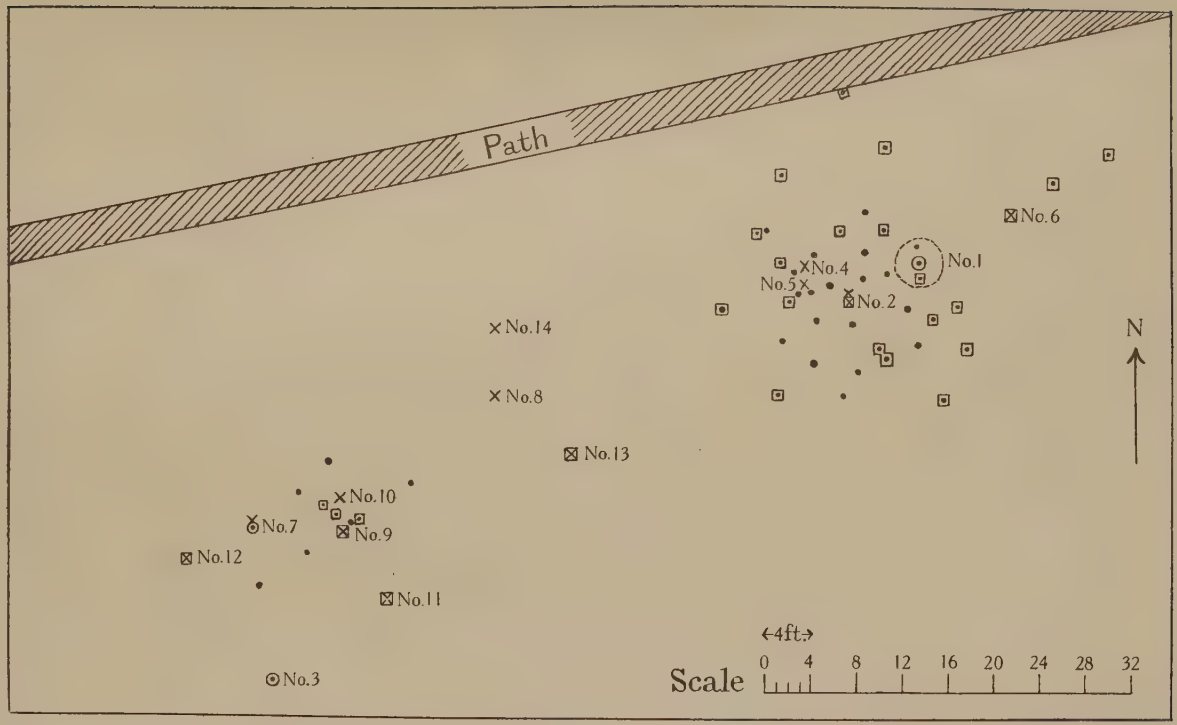

Fig. 1. Plan of the nests on the area, and the maximum distances travelled by the ants. *Acanthomyops flavus*: nests ⊙. *Myrmica ruginodis*: nests ×, max. distances • . *Formica fusca*: nests ⊠, max. distances ⊡ . Mixed *flavus-ruginodis* nest ⊗. Mixed *fusca-ruginodis* nest ⊠.

that these ants had come from nest 4. I regret now that I did not mark several ants whilst nest 4 existed, as in this way definite proof of the change could have been found.

Nest 5 also proved to be a temporary one, as by 7 September 1935 not an ant could be found on digging under the stone. I turned up all the stones around for a distance of 5 ft. or so but could not find any traces of the creatures. I presume that they returned to the parent nest 2 or died. As far as I could determine only workers and pupae seemed to be present—this was observed when the stone was removed (no digging occurred until the ants had moved to a fresh stone).

Most of the observations on territory were made on ants travelling from nest 2. Several were made on ants travelling from nest 10 where the greatest distance travelled (10·25 ft.) was recorded. As with the species dealt with above, foraging took place generally and in all directions so that the area of the territory covered by these ants can be taken as that of a circle with the nest as centre and the maximum distance travelled by the ants as radius. This is 330·18 sq. ft.

Foraging by these ants is undertaken either singly or in numbers. On one occasion I saw a party of 12 ants sally forth from nest 2 to a badly decomposed caterpillar. They began feeding on the creature on the spot. I then removed the remains for identification, but found them too badly decomposed. This party of ants travelled 9·5 ft. from nest 2 and, in spite of the dense vegetation, made straight for the spot where the caterpillar was lying (15 August 1935).

On another occasion (29 August 1935) I found two *M. ruginodis* workers carrying a de-alated female away from nest 10. I discovered them a few inches from the nest, and watched them carry her for a distance of 4 ft. They then dropped her, and I took her away for examination. I dug up this nest two days later to take its census, and no female was found in it: this incident probably accounts for its absence (see Table 2).

On this same date, I witnessed an unusual reaction of *Formica fusca* to that usually found when it meets a specimen of *Myrmica ruginodis*. On lifting the stone covering nest 9 (*Formica fusca*), so as to allow a *Myrmica ruginodis* to proceed on its way uninterrupted, many of the *Formica fusca* scattered, and the former ant entered the uncovered nest. It was immediately seized and carried below. I suppose the fact that a large number of the *Formica fusca* species were present or the closeness to the nest made them behave differently to when foraging singly, or in small numbers.

5. Populations of the nests

The populations of the nests were obtained by counting the living inhabitants. In this way the number of each caste and of immature forms could be found. As many of the nests were small and could easily be dug up and removed, no appreciable loss of ants occurred. With the larger nests (Nos. 1, 3

and 10) the soil was carefully searched on the spot and all odd ants, larvae, pupae etc., placed in the bag. The following day the nest was again disturbed and any ants found removed. In this way I hope I have got the total population in each case.

As mentioned by Elton (**1**) and found to be the case myself (**2**) at Garforth, the size of the mound or the stone does not indicate the size of the population. This is shown to be so in Table 1.

Table 1

No. of nest	Type	Size sq. ft.	Total population
1	Mound	12·6	5743
2	,,	7·08	528
3	Mound and stones	3·14	5613
4	Stone	0·11	Temporary
5	,,	0·13	,,
6	,,	0·29	275
7	,,	0·27	Temporary
8	,,	0·43	660
9	,,	0·77	218
10	,,	0·18	1534
11	,,	0·21	65
12	,,	0·33	73
13	,,	0·33	143
14	,,	0·99	233

As the nests were dug up either in the early morning or else in the evening, the populations given are the maximum for the nests. As was to be expected from the nests being dug up in summer and autumn, immature forms were found as well as workers and the sexual forms. An analysis of the number of each caste (worker, male and female) as well as the number of larvae, pupae and callows found in each nest examined is given in Table 2.

Table 2. *Analysis of populations of the nests*

Name of species	No. of nest	Date	Workers ☿	Males ♂	Females ♀	Larvae	Pupae	Callows	Total
Acanthomyops flavus	3	9. viii. 35	3880	641	33*	90	877	92	5613
	1	5. x. 35	5240	141	362*	—	—	—	5743
Formica fusca	6	29. viii. 35	172	—	1	—	84	18	275
	12	30. viii. 35	50	—	1	—	18	4	73
	9	30. viii. 35	190	—	1	—	22	5	218
	11	7. ix. 35	65	—	—	—	—	—	65
	13	21. ix. 35	115	—	1	—	27	—	143
	2†	21. ix. 35	248	—	1	—	—	—	249
Myrmica ruginodis	2†	21. ix. 35	248	—	1	—	30	—	279
	10	31. viii. 35	1281	4	—	249	—	—	1534
	14	7. ix. 35	171	—	1	52	9	—	233
	8	30. ix. 35	623	—	1	36	—	—	660

* Winged females. † Mixed nest referred to in the text.

The nests of *Acanthomyops flavus* have the greatest number of individuals, those of *Myrmica ruginodis* come next, whilst those of *Formica fusca* have the lowest number. Two of the latter nests (Nos. 6 and 2) have more ants than the smallest nest of *M. ruginodis* (No. 14). On the whole the *F. fusca* nests were

very small and I think it is safe to say they were less populous than those of *M. ruginodis*.

It will be noted that all the permanent nests were included in the census: therefore with the exception of the population of nest No. 7 we have a record of the total number of ants on the area —that is, assuming that nests 4 and 5 were merely attempts at branch nests and returned to nest 2. The total number of ants was 15,085 on an area of 1052 sq. yd., before the marriage flights had occurred in the *A. flavus* nests. Apparently the marriage flights had occurred in the other two species. However, this represents the number of ants in August and September of 1935.

The absence of pupae and callows in nest 1 was due to the fact that this nest was dug up last; however, they would by this time have developed into adults, so that the total population record was not affected much.

The distribution of the ants in the nests was in all cases fairly uniform, even in nest 1, although the heated surface of the nest may have induced greater activity, I found all the castes to be evenly distributed as I dug down. In the case of the *Myrmica ruginodis* nests, the distribution was vertical, i.e. the chambers extended downwards more than outwards.

6. Density of population

Density of population may, as Elton (**1**) mentions, be of three kinds. The greatest density is the greatest number in the nests at any time. As the nests were dug either in the evening or early morning, the total population of each nest represents the greatest density. The economic density is found by dividing the total nest population by the total territory. The lowest density is found by dividing the total nest population in each species by the total area of the census.

As *Acanthomyops flavus* has no territory, then the only density of population in this case is the greatest density. Table 3 shows these densities. As the

Table 3. *Densities of population*

Name of species	Total population*	Territory per nest	Economic density = Total population / Total territory	Lowest density = Total population / Area of census†
Acanthomyops flavus	10,479	Nil	Nil	Nil
Formica fusca	872	236 sq. yd.	0·615 per sq. yd.	0·828 per sq. yd.
Myrmica ruginodis	2,667	36·7 sq. yd.	18·167 per sq. yd.	2·535 per sq. yd.

* This does not include pupae. † The area of the census is 1052 sq. yd.

territory is the feeding ground for the ants, in the estimation of the densities of population pupae are not included, as they are not fed.

The commonest ant on the area is *A. flavus*, but as this seldom leaves the nest it is rarely seen. This is followed by *Myrmica ruginodis*, which, although it has fewer nests than *Formica fusca*, has more individuals due to the greater

populations of the nests, the nests of *F. fusca* being in some cases very small. The least common ant is *F. fusca*.

The reason that the economic density of *F. fusca* is less than the lowest density is because the total territory of the six nests, which amounts to 1416 sq. yd., is greater than the area of the census, 1052 sq. yd. This means that there is considerable overlapping of the territories, consequently certain parts of the area are common territory to two or three nests of this species.

7. Response to weather conditions

The area, owing to its position, is favourable to ant activity throughout the summer months and spring and autumn. Owing to the slope, the angle of incidence of the sun's rays, especially in the middle of the day, approaches the normal. This causes the area to become very hot in summer. The bracken holds the heat and prevents the breeze from penetrating to the ground. On reaching the area to make observations during the summer months, and stepping off the path into the bracken, one felt as if one was stepping into a vapour bath, the air being very hot and still. Being shielded by the hill from the north and north-east winds the area remains warm until late autumn.

I found that, of the two active species, *Myrmica ruginodis* retired sooner than *Formica fusca* to rest for winter. On 28 October 1935 *Myrmica ruginodis* had ceased to be active, whilst *Formica fusca* were still about; after that date no further activity occurred. The hot sunny days of August were the periods when activity was greatest. As mentioned earlier, after a rain storm *Acanthomyops flavus* assumed greater activity; at this time they added soil to the entrances as described elsewhere.

8. Food of the ants

As *Acanthomyops flavus* does not forage for its food it gets its nourishment from root Aphides (**3**). In my investigation I have been unable to find any Aphides, or any of the little black eggs. I found however that the ants licked broken roots of bracken, and in some cases they were found biting the roots. In an artificial nest they eagerly devoured pieces of pear, and the pulp from a plum stone. A cranefly was also dismembered. As the nest (No. 1) is surrounded by the branches of brambles, perhaps in the autumn the ants partake of the fruit; some of the stems touch the mound of nest No. 1 and therefore foraging is not necessary.

Aphides were not found on the bracken, in fact the vegetation was remarkably clear of insects, this being due most probably to the fact that the hillside catches fire almost annually, the surface soil being composed chiefly of burnt vegetation. I was afraid this might occur during my survey, but luckily it did not, although fires are frequent.

I found however that, like *Acanthomyops flavus*, *Formica fusca* ate the pulp from plum stones, and from the core of a pear. Over-ripe blackberries were also devoured in an artificial nest.

That *Myrmica ruginodis* is a flesh eater is proved beyond doubt by the expedition to the decomposed caterpillar mentioned previously.

The ants were notably crawling about "empty-handed", no parts of insects or exceedingly few being carried.

9. Acknowledgments

I wish to thank Mr H. St J. K. Donisthorpe for kindly identifying the ants; the Agent to the Savile Estate, Mr C. A. E. Horton, for permission to use the land; and Mr Charles Elton for help and encouragement.

10. Summary

A survey was made of three species of ants living on a hillside at Thornhill, Yorkshire, in 1935.

Territory. *Formica fusca* has the largest territory, 236 sq. yd. per nest. *Myrmica ruginodis*, the only other species to have territory, has a much smaller area per nest, namely 36·7 sq. yd. *Acanthomyops flavus* has no feeding territory at all outside the nest.

Populations. The most populous nests are those of *Acanthomyops flavus*, and the least populous those of *Formica fusca*, the latter being in most cases very small. *Myrmica ruginodis* has the greater of the two economic densities, whilst *Acanthomyops flavus* has none at all. Although the latter ant is the commonest on the area, owing to its secluded habits it is seldom seen. The one most commonly seen being *Myrmica ruginodis*.

Food. Perhaps the fact that nearly every summer, the hillside on which the area is situated suffers from the bracken catching fire, accounts for the absence of Aphides and the lack of insects generally. *Formica fusca* and *Acanthomyops flavus* ate fruit in artificial nests, so that the plentiful supply of blackberries in autumn may be one source of food.

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2. **Pickles, W. (1935).** "Populations, territory and interrelations of the ants *Formica fusca*, *Acanthomyops niger* and *Myrmica scabrinodis* at Garforth (Yorkshire)." J. Anim. Ecol. 4: 22.
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THE SHINYANGA GAME EXPERIMENT: A FEW OF THE EARLY OBSERVATIONS

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(*With Plates 7 and 8 and 5 Figures in the Text*)

FOREWORD

By C. F. M. Swynnerton

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A note on the object of the experiment is perhaps called for. The game animals feed the tsetse flies and act as hosts also for the pathogenic trypanosomes. In consequence their extermination has frequently been advocated and in some colonies great slaughters have already taken place. I have personally taken the view that the game fauna of Africa is too precious an asset to be lightly destroyed if we can find any other means of destroying the tsetses; and we have laid ourselves out, as a Department, to discover these other means. At the same time it is certain that a modicum of game destruction must here and there take place where other measures will not suffice. I accordingly laid down this scheme of experiment, which Harrison is carrying out so ably, for the purpose of learning all we can of the relations of the game animals and the flies, in order to ascertain the minimum amount of game destruction which will anywhere suffice for our purpose, and with the idea, also, of supplying the scientific control which has been lacking in the great slaughters of game that have taken place elsewhere. In conjunction with these experiments, the preferences of the flies are being tested in the laboratory: it may be that some species of mammals are nauseous to the flies and need not be attacked. Irritability, tendency to use open country, and defensive fur may protect other species. The mere absence of the animals from the flies' feeding grounds in the period of stress (late dry season) may suffice. We are still at the beginning of the subject, but I wish to make it clear meantime that the hope underlying the experiment is that, where game destruction has to be used, discriminative destruction may suffice.

A. The investigation

An experiment is being carried out by my Department as a contribution to the solution of the intricate problem of "The Relations of Game and Tsetse". The following brief description and the maps that accompany this paper will make the scheme clear. The latter is being described also by Mr Swynnerton in his report "The tsetse flies of East Africa: a first study of their ecology with a view to their control", which the Royal Entomological Society is publishing. This should also be seen (under *Glossina swynnertoni*) for a fuller account of the country and types of woodland.

The gently undulating thorn-bush country in which the experiment is sited has a moderate game population, which comprises a number of species. The tsetse *G. swynnertoni* is fairly dense and the elusive *G. pallidipes* is also

to be met with, although it is at present rather scarce. The experiment proper covers four blocks of country, each block except 10 A being divided from the others by clearings at least 800 yd. wide as a check to the passage of the

Fig. 1. Shinyanga game experiment, the habits of two species contrasted. Kudu and zebra.

flies. The blocks are numbered thus: 9, 10 A, 10 B and 10 C. 10 A is at present divided from 9 by a barrier (to the tsetse fly) of thicket, but at a later date will be divided also by a wide clearing to be hacked out of 9. 10C2 has yet to be divided by a clearing from 10B. Blocks 9, 10B and 10C are each cut into

squares of 2000 yd. each side by path transects. 10A, however, has squares with sides measuring 500 yd. The squares were marked out by means of a prismatic compass, north-south and east-west, the transect paths being hoed.

A botanical survey is being carried out and for 10A and 9 is nearly completed. The main plant communities in each square are being mapped and are

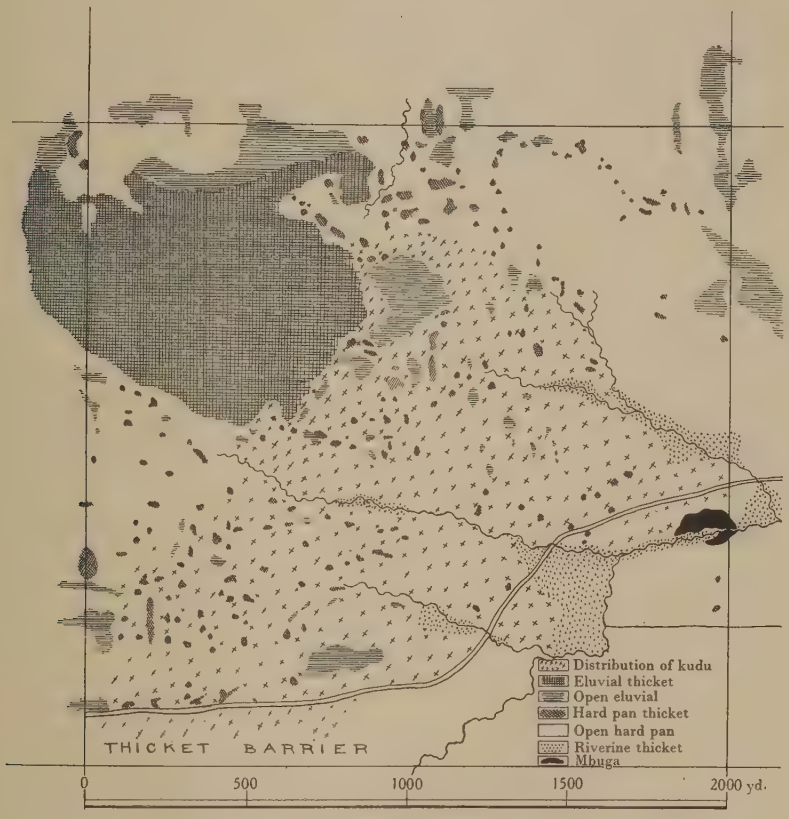

Fig. 2. Block 9. Square C 1.

described as follows: *Eluvial Savanna* (Fig. 1), *Eluvial Thicket* (also Fig. 1), *Hard-pan Savanna* (Fig. 1), *Hard-pan Thicket*, *Riverine Thicket* and *Mbuga* (black soil and seasonal swamp, Fig. 1). In 10A the course which vegetational succession will take when the annual grass fires are discontinued is being tested by not burning the grass. The same is being done in 4A shown in Fig. 1, but in rather a different connexion. The successional effects, direct and indirect, on the game and the fly are also being watched carefully.

Earth tanks, dug in soil that will hold water, have been constructed for the conservation of water for the use of the game, and, later on, salt licks will be put down to encourage the latter in the blocks we shall use as sanctuaries. Patrols are being carried out by native game scouts, each scout having two "rounds"; that means that each game round—and the whole of the transects in the blocks—are patrolled every second day. The duties of the scouts are to write down the species of game seen, the number of animals each herd contains, and the square in which it was seen. Daily records are kept. Where the species is nocturnal its spoor is recorded. A check is kept on the scouts by their having to record the spoor of the writer, who is in charge of the experiment. While out on the field work he visits the various rounds. Failure to record his spoor by the scout whose round has been visited shows that the latter is not doing his work properly. The numbers of each of the more conspicuous species in each block are now known and a sudden influx of game is immediately investigated specially, so imaginary herds cannot be recorded with impunity.

Fly rounds are carried out twice a week on consecutive days and bait screens are used to attract the flies. The standard to which all figures are brought is the number of flies, and the number of each species of food animal per 10,000 yd. of transect. The experiment, as planned, is divided into six phases.

First phase in all blocks. Reconnaissance and regular rounds to obtain the distribution, density, movements and habits of all local food animals of the flies. The same for the flies themselves. Interrelations of flies, food animals and vegetation.

Second phase. From block 10B all animals larger than impala (*Aepyceros melampus suara* (Matschie)) will be driven (but so far as possible guided) into 10A and 10C where "earth" water-tanks and salt licks have been provided in order to make these blocks popular with them. In block 9 game will be harassed in the flies' feeding grounds, but with as little actual killing as possible. All observations, game and fly rounds will continue, to note closely the effect the measures have on the flies.

Third phase. Elimination of impala (*Aepyceros melampus suara*) and all animals smaller than impala, except dikdik (*Rhynchotragus kirkii cavendishi* Thos.) and wart hog (*Phacochoerus africanus aeliani* Cretzschmar) from 10B. Harrying of game to continue in block 9. Game and fly rounds to continue in all blocks, to find what effect the above has had on the fly.

Fourth phase. From 10B all animals possible to be eliminated if the flies still persist. General hunting in 9, but guided, to drive the game into 10A and 10C. Game and fly rounds to continue in order to find out the effects.

Fifth phase. Organized killing of survivors in 9 in an attempt to eliminate all game animals—provided that the flies are still present. Part of the object in this case will be to see if it is even possible to eliminate all food animals to the extent of eliminating the flies in the type of country concerned.

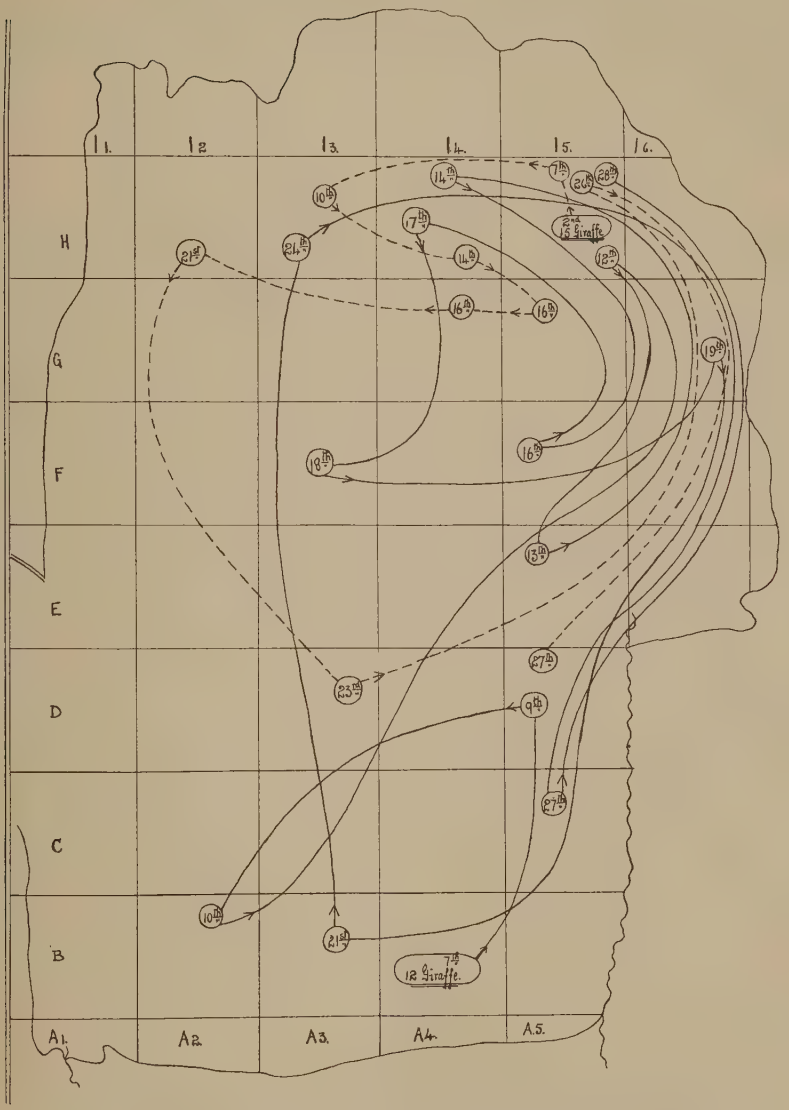

Fig. 3. Block 9. A monthly game chart for March 1936. Showing movements of two herds of giraffe.

Sixth phase. A year's final examination of the situation to ascertain the full effects of the operations on the flies and find what animals they may still be feeding on. The animals left would doubtless be dikdik (*Rhynchotragus*

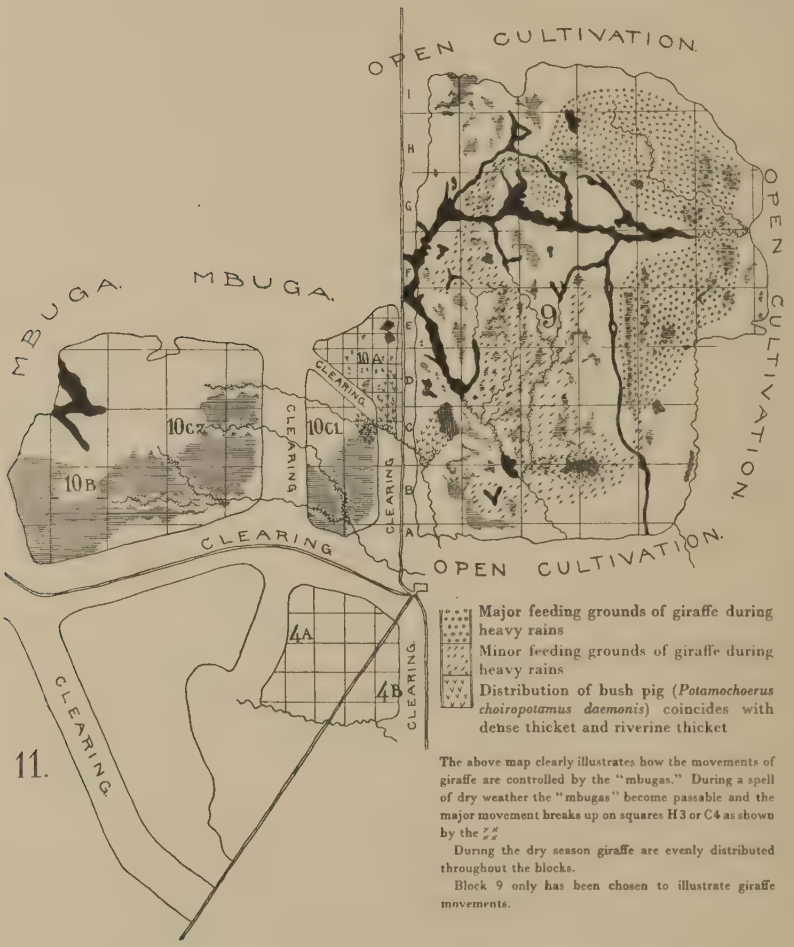
OPEN CULTIVATION.
OPEN CULTIVATION.
MBUGA.
MBUGA.
9
10A
10C2
10C1
10B
CLEARING
CLEARING
CLEARING
CLEARING
CLEARING
OPEN CULTIVATION.
4A
4B
11.
Major feeding grounds of giraffe during heavy rains
Minor feeding grounds of giraffe during heavy rains
Distribution of bush pig (*Potamochoerus choiropotamus daemonis*) coincides with dense thicket and riverine thicket
The above map clearly illustrates how the movements of giraffe are controlled by the "mbugas." During a spell of dry weather the "mbugas" become passable and the major movement breaks up on squares H3 or C4 as shown by the ZZ
During the dry season giraffe are evenly distributed throughout the blocks.
Block 9 only has been chosen to illustrate giraffe movements.

Fig. 4. The Shinyanga game experiment. The habits of two species: giraffe and bush pig.

kirkii Günther) and the families Viverridae, Felidae, Leporidae and Muridae, the members of which it is impossible to eliminate over large tracts of country.

General note. While the above experiments are being carried out, and in so far as time and staff will allow, an investigation on ecological lines of population, interrelations and habitat of all food animals of the fly will continue. Trapping

of flies will take place in 10C, when game is sufficiently concentrated there, as the presence of game amongst them appears to assist the traps. 10A is being kept unburned and observations will be carried out there to see the effect of

OPEN CULTIVATION.
OPEN CULTIVATION.
OPEN CULTIVATION.
MBUGA
MBUGA
CLEARING
CLEARING
CLEARING
CLEARING
CLEARING
10A
10C2.
10C1.
10B.
9
OUTER CIRCLE
4A
SUCCESSION
4B
CONTROL
11.
Main Impala habitats during wet season in Block 9
The dry season habitat has changed by the bush becoming more dense through increased foliage with areas of long grass. This has had the effect of forcing out 70% of the Impala into the squares marked . These squares contain large areas of very open short-grassed "hard pan", the open country on the edge of the block being also used during the night. The remaining 30% of Impala are distributed through the block on small patches of short-grassed "hard pan". After the annual burning of the grass they return to their old habitats and are evenly distributed throughout the block.

Fig. 5. The Shinyanga game experiment. Impala movement in the wet season.

large numbers of game in counteracting (possibly), by their influence on the vegetation and fly, the adverse influence on the flies which not burning the grass over some years brings about.

Computation of the smaller animals is proving difficult and special methods will have to be evolved in each case.

B. Indications of the succession (plant and animal)

Annual burning of the grass by man over a long period has reduced the cover and made the habitat dry by increasing the direct evaporation from the soil during the season when leaves, and the transpiration therefrom, are falling. Organic matter from the plants is not allowed to accumulate and the very open plant communities which the fires have given rise to are being invaded by xerophytes. Thus a xerosere has probably been initiated.

Where, however, as in 10A and 4A, succession is being advanced by non-burning, a grass mat is protecting the soil from the wind and sun and is holding the organic matter that falls from the woody vegetation. The latter, with the grass, is forming humus to enrich the soil and increase its water-holding capacity. The growth of small woody plants and shrubs is uninterrupted, dense thickets are formed on the eluvium especially and the plants tend to retain their leaves until well on in the dry season. This ensures an enlarged supply of food for the animal community. The dominant trees of the well-drained eluvial rises are *Commiphora Fischeri* Engl., *Commiphora ugogensis* Engl., *Ostryoderris Stuhlmannii* Dunn. and *Strychnos heterodoxa* Gilg. and the chief shrubs (coming into great prominence with non-burning) are *Abrus Schimperi* Hochst., the Markhamias (*M. lanata* and *M. acuminata* Schm.) and *Grewia* of more than one species.

In the hard-pan plant communities also thickets are being formed of *Commiphora Schimperi* Engl., *Fagara Merkeri* Engl., *Combretum parvifolium* Engl., *Grewia praecox* K.Schm. and other species. These in turn are being encroached on gradually by the dominant shrub of the eluvial community, *Abrus Schimperi* Hochst., accompanied by *Markhamia acuminata* Schm. and *Grewia platyclada* K.Schm.

On the open mbugas thickets are growing up of *Dichrostachys glomerata* Hutch. & Dalg. and *Ormocarpum trichocarpum* Harms., and *Acacia drepanolobium* Harms. is increasing its dominance as the chief tree. *A. spirocarpa* Hochst., *A. senegal* Willd., *Commiphora Schimperi* and the small shrub *Maerua trichophylla* Gilg. are gradually encroaching.

Thus new environments are being created by the vegetational succession. Previous to the advancement of the latter, the open, short-grassed country was eminently suitable for impala (*Aepyceros melampus suara*), roan (*Hippotragus equinus* Desmarest) and dikdik (*Rhynchotragus kirkii cavendishi*). These are now gradually being pushed out and are being replaced by the East African greater kudu (*Strepsiceros strepsiceros bea* Heller) and apparently (temporarily) duiker (*Silvicapra grimmia* Gray). Bush pig is becoming more numerous and bush buck begins to figure in the records.

Phot. 1. Tree and thicket communities on eluvial soil. The two trees shown are *Commiphora ugogensis* Engler. Amongst the shrubs, small leafed, is *Abrus Schimperi* Hochst. Eluvial savanna and thicket, when combined with riverine thicket, forms the home of the Greater Kudu in Shinyanga, on which see p. 283 and Fig. 1. To be contrasted with the zebra's requirements (Fig. 2 and Fig. 1).

Phot. 2. A Dikdik (*Rhynchotragus kirkii cavendishi* Thos., see p. 284).

C. PRELIMINARY NOTES ON A FEW OF THE MAMMALS

The subspecific names used in this paper are based on the probabilities of distribution rather than on an actual examination of skins collected in Shinyanga. This omission is to be rectified, and any alterations necessary will be given in a future paper.

1. *Masai giraffa* (Giraffa camelopardalis tippelskirchi *Matschie*)

The most frequently seen animal of the general experimental area. Its main habitat here is the hard-pan plant community in which much of its food is obtained and beside which it can shelter in the heat of the day. It feeds through the very open bush of the hard-pan, its food preferences being *Commiphora Schimperi* Engl., *Albizzia Harveyi* Fourn., *Cassia goratensis* Fres., *Dichrostachys glomerata* Hutch. & Dalz., *Harrisonia abyssinica* Oliv. and *Terminalia Stuhlmannii* Engl., while in the open eluvial plant communities its preference is for *Markhamia acuminata* and *Sterculia triphaca* R. Br.

During the dry season giraffes have been seen eating the bark of *Euphorbia bilocularis* N. E. Br. despite the acridity of its latex. This must have been an exceptionally difficult method of obtaining food owing to the formation of the prehensile upper lip, and the bark must have been scraped off by the incisors of the lower jaw. As many as six giraffes have been seen together feeding on a *Euphorbia* cut down 2 days previously, while others have been seen feeding on the standing trees.

The trees most frequently used for shade are the tall *Acacia rovumae* Oliv. and *A. spirocarpa* Hochst. When resting the giraffes may be found in small numbers under each tree. Threes and fours have been observed, and in many instances three have been sitting down while the fourth was standing and apparently on guard. On the other hand, it is quite a usual sight to see a solitary individual standing asleep in the shade of a large tree, relying solely upon his accompanying party of tick birds (*Buphaga*) to give warning of approaching danger.

Should the tracks of the giraffes lead into a thicket, it will be found that they are at its narrowest point and on a short cut to the next feeding ground. Herds of up to 45 individuals are frequently seen returning from water, but these large herds are continually breaking up into small parties. These again, meeting with others, form a new large herd, which again breaks up: and so on. The giraffes are occasionally accompanied by eland (*Taurotragus oryx pattersonianus* Lyd.) and zebra (*Equus quagga granti* de Winton) which seem to realize that they are perfectly safe and will receive due warning of approaching danger while they are in their company. The signal of danger to the rest of the herd is a loud "blow".

Water is essential to giraffes and they appear here to drink every third day. Sight, hearing and scent are most acute. Lions are their chief enemies and the

number of bones bleaching in the sun is proof of the heavy toll taken by them. Young giraffes are most frequently seen during the rains and are most conspicuous in the months of October to July, but occasional young are born throughout the year.

2. *Upland zebra* (Equus quagga granti *de Winton*)

The habitat of the above animal is very open hard-pan and the edge of mbugas. Very little shade is necessary for it during the heat of the day. The dominant trees along the mbuga edge are *Lannea humilis* Oliv. merging into open hard-pan plant communities of *Acacia spirocarpa*, *Commiphora Schimperi* and *Dalbergia melanoxylon* Guil. & Per. Facilities for speed and food are the dominant factors governing the zebras' choice of habitat, and water is essential.

Their food consists of grass, but on rare occasions they have been seen to eat the fresh shoots and leaves of *Capparis tomentosa* Lam. and *Thylachium africanum* Lour. during the dry season. Speed is their only means of escape, although amongst themselves they fight very fiercely, using teeth and hooves, and lions' jaws have been found broken, probably by the kick of a zebra. Each troop is kept together by the stallion, who will not allow individuals to enter from other troops. On many occasions the writer has watched two troops in close vicinity, the leading stallions driving away with bared teeth any member of the opposite troop venturing too close.

Lions are their chief enemies and this probably contributes to the choice of the open spaces with high visibility. Young are born during the rainy season, but occasional foals are dropped throughout the year.

Wet season. During the rains, and in the tall grassed areas, they may continually be seen with a herd of giraffe. They undoubtedly rely to a great extent on giraffes to give the alarm of approaching danger. The writer has stalked to within 12 yards of zebra in long grass, being eventually spotted by one of the giraffe in the near vicinity, who immediately gave the alarm which was spontaneously acted upon by the zebra. They realize the use of the giraffes, especially when resting during the heat of the day.

3. *Equatorial impala* (Aepyceros melampus suara (*Matschie*))

The habitat of the impala is the short-grassed open-parkland country. Shade is necessary during the heat of the day. Their needs are definitely in evidence in the choice of their habitat. Not only does it supply them with food and shelter, but it enables them to use their marvellous jumping powers when in danger. Occasionally during the dry season they search for food in rather dense bush and are then a sure prey for their enemies. On these occasions they cannot jump and when an opportunity does occur they hesitate.

Their chief enemies are the leopard (*Felis pardus suahelicus* Neum.), chita (*Acinonyx jubatus* Schreb.) and wild dog (*Lycaon pictus lupinus* Thos.). On many occasions the writer has seen a kill made by the above enemies and

always in fairly dense bush. The warning given in danger is a loud snort. The rams are not very observant and rely solely upon the females to give the alarm of approaching danger, except in the breeding season, when the procedure is entirely reversed, the rams becoming observant. Wild dogs being their chief enemies they are used to them and do not scatter unduly. The method of the dogs is to single out one from the herd and pursue it relentlessly till exhausted, or drive it into and kill it in a thicket.

The food of impala consists mostly of grass, being occasionally supplemented by young shoots of shrubs and trees. They are able to adapt themselves to severe dry season conditions and often live without water, the latter being replaced by luscious plants from riverine thickets and especially by the wild *Sansevieria*. The leaves of this genus contain much juice, the fibre remaining after mastication being discarded.

Impala are essentially gregarious and the herds never vary except during the mating season when the young males are ousted and themselves form herds composed entirely of males. The number in each herd varies considerably, as many as 50 being seen. The herds composed of males vary from 28 to a single individual, which in the latter case is an old male, ousted from his leadership of the herd and preferring a life of solitude. During the night they come out into very open country and, if clearings are near, these are used. This is purely a matter of protection, enabling the animals to utilize their jumping powers if in danger with a knowledge that there are no obstacles in their path.

The young are born during the rains and have been seen during November and onward.

Wet season habitats of impala. When the rains commence, increasing foliage makes the open eluvial plant communities more dense, which, together with the long grass, makes visibility exceptionally bad for the impala, and sight, their most acute sense, becomes practically useless except to assist their progress. Hard-pan patches usually inhabited by many herds are gradually evacuated as the grass gets longer, while the short-grassed "hard-pan" areas are able to support a limited number only, these rarely moving away from its vicinity. Gradually a movement commences to the edge of the bush where the open country is more suitable for feeding, while during the night it offers protection where sight and their jumping powers can be utilized to the greatest advantage when in danger, the edge of the bush supplying shade during the heat of the day. Impala in long grass are at a hopeless disadvantage, they are so concentrated on the effort of pushing through the grass and watching their direct front, that it is quite possible to walk as close as 40 yards in their rear. One immediately realizes to what extent they depend on sight. This temporary forcing out during the wet season through changing habitats may be very usefully compared with what will happen in the blocks where succession by non-burning is being tested and will probably show how the above species may be forced out permanently.

4. *East African roan antelope* (Hippotragus equinus langheldi *Matschie*)

The habitat of the roan is the open hard-pan country and semi-mbuga where grass is plentiful. Shade is necessary during the heat of the day and is supplied on semi-mbuga by *Acacia drepanolobium*, *A. seyal* Del., *A. formicarum* Harms. and *Dalbergia melanoxylon*. On hard-pan plant communities it is furnished by *Acacia rovumae*, *A. spirocarpa* and small clumps of thicket of *Combretum parvifolium*, *Grewia praecox* and *Anisotis* sp. Very little shade satisfies roan antelopes. They are grass feeders but occasionally young shoots and leaves of shrubs, as of *Thylachium africanum*, are eaten, especially during the dry season.

5. *East African eland* (Taurotragus oryx pattersonianus *Lyd.*)

During the rains most of the food of this antelope is obtained in the eluvial plant communities where succulent convolvulaceous herbs (*Ipomaea* spp.) are abundant and greatly favoured. The rambling herb *Commellina africana* L., being one of the first to appear, is a great attraction and where this plant is much in evidence eland may always be seen. During the rains a herd of 80 occasionally visited a block of country, staying for a few days, then returning to the plains. In following up their spoor for food plants, it was discovered that *Commellina africana* was the plant preferred. Of the climbing plants *Vigna triloba* Walp. receives most attention.

Eland also feed through the bush on fresh shoots and leaves of shrubs and trees. Of the former, the preference locally is for *Grewia praecox*, *G. platyclada* and *Abrus Schimperi*; of the latter, for *Commiphora Schimperi*, *Markhamia acuminata*, *Hymenodictyon parvifolium* Oliv. and *Sterculia triphaca*. They are exceptionally fond of the fruits of *Sclerocarya birrea* var. *multifoliolata* Engl., which, when fallen, they pick up from the ground. When standing chewing their cud, they disgorge the large seeds of this species: on three occasions the writer has disturbed eland, and in each place where they were standing were small heaps of freshly disgorged seeds of *Sclerocarya*. Occasionally during the dry season they chew the fleshy leaves of aloes to obtain moisture.

During the day they prefer the open lightly bushed country on the edge of plains or "mbugas". On the latter *Lannea humilis* is the dominant tree with a gradual transition into the hard-pan plant communities of *Commiphora Schimperi*, *Acacia spirocarpa* and small clumps of thicket of *Combretum parvifolium* and *Anisotis* sp.

Lions are the chief enemies of eland. Occasionally they are accompanied by a herd of roan (*Hippotragus equinus langheldi*) or zebra (*Equus quagga granti*). In the evening or early morning they may be seen on their feeding grounds, returning to the open country after sunrise and during the heat of the day standing under shady trees there. This animal may prove to be of great economic value. In captivity it is very docile and tractable. There is no reason why it should not be used to replace oxen where the country is fly-infested.

Phot. 3. An "mbuga"; alluvial flat of black "cotton soil" grass-land, very wet in the rains and cracking heavily in the dry season: zebra crossing it. Shown black on the maps.

Phot. 4. Nearly open "hard-pan" with zebra. Ground that is thus underlain by a hard-pan of iron oxide or calcareous cement, carrying its own tree savanna or open, is shown white on the maps. For the connexion of various game-animals with it see pp. 279, 280.

6. *East African greater kudu* (Strepsiceros strepsiceros bea *Heller*)

Thickets both eluvial and riverine are essentials in the habitat of greater kudu to supply them with food of a luscious nature and enable them to maintain their existence without having recourse to water. They provide also shelter for them during the heat of the day, a retreat when danger threatens and breeding places in which their young are well protected. Riverine thickets (the river beds being without water during the dry season) contain plants of a luscious nature which supply the kudu with both food and moisture. Even in the driest months of the year, they will feed, without drinking, round a pool of water where plants suitable for their requirements are in evidence,.

During the breeding season they retire into dense thickets where they remain until their young are sufficiently strong and are able to maintain the speed of their parent in danger. Their distribution is limited chiefly by their reaction to cover. They are inoffensive and incapable of defence, and do not possess either the speed or stamina wherewith to outvie their enemies, consequently they are a sure prey if exposed. In the evening and early morning they may be seen in fairly open country where they have been feeding through the savanna bush, yet never far from the thickets whither they return after sunrise (see Figs. 1 and 2).

Their chief enemies are wild dogs (*Lycaon pictus lupinus* Thos., the East African race) and a more ruthless foe cannot be imagined. While the latter are in the vicinity, kudu will remain in their thicket retreat for several days. From the above it will be observed that their habitat has been adopted as a refuge. They usually congregate in small numbers of from 3 to 8, but occasionally a herd of 20 may be seen. Kudu that have been killed by lions are frequently seen.

When large numbers of greater kudu are seen together, it is a sure sign that a migration has occurred from the next block of country. These periodic migrations occur during the night and are usually led by three or four males, yet the herd soon breaks up into small numbers again. Food may be the deciding factor governing these migrations—that remains to be proved. It may be surmised that, as they do not drink water, luscious plants must supply the kudu with sufficient moisture for their needs. Thus in some localities they eat *Euphorbia tirucalli* L. bushes right down in the dry season while leaving them alone in the wet. The impala adapts itself to severe dry season conditions by chewing wild *Sansevieria* and other luscious plants while living still in the open. The kudu in the same season haunts the cool atmosphere of the streamside thickets more than it does in the rains.

When disturbed during the heat of the day, kudu will not run far. In comparison with the majority of antelopes their pace is very slow, and, when continually followed, they go from thicket to thicket, always resting in the shade. They keep out of the sun as much as possible. The warning given to the

rest of the herd is a loud hoarse bark, given by one of the females. If an old male is with the herd, he will, at the first warning, break away from it and go for the densest patch of thicket. Then, with his head thrown back to get his horns along his back, he will force his way through with marvellous ease for such a large animal. He prefers a life of solitude, using the densest patches of thicket as his habitat. Frequently during the mating season he will separate his choice from the herd and return with her to his retreat. If the spoor of the old male is followed up, he will in all probability be found feeding behind a bush and if he has seen you he will remain perfectly still, the bush acting as a screen, until he discovers that he has been seen. He then breaks away and uses the bush as cover by keeping it in a direct line between himself and his enemy. In comparison with the female he is clumsy and ungainly in gait, yet one of the finest of sights is a big male standing—unsuspicious, a perfect picture of symmetry and an object in nature's garden which cannot be surpassed for beauty.

7. *Common duiker* (Silvicapra grimmia *prob.* nyansae *Neum.*)

The habitat of the common or savanna duiker is the lightly bushed and heavily grassed areas and its choice of habitat is governed by its ability to dodge or continually break off at angles through the long grass. They are thus able to deceive their enemy who may be following by scent or sight. In either case the pursuit is soon discontinued owing to slow progress. From the food plants collected it is evident that the "hard-pan" areas receive preference as a feeding ground. The leaves and young shoots collected have been as follows: *Dichrostachys glomerata* Hutch. & Dalz., *Acacia spirocarpa* Hochst., *Combretum longispicatum* Engl., *Asparagus Pauligulielmii* Sol., *Cissus* sp., and *Ipomaea* sp.

Duikers may be observed in the early morning returning from their feeding ground to the heavily grassed areas, where they find shelter from the sun under a shady bush or small tree. They are quite easily overlooked, not moving until one is a few yards from them. Except during the breeding season, they are solitary. Leopards and wild dogs are their chief enemies. The young are born during the rains, from November onwards.

8. *Cavendish dikdik* (Rhynchotragus kirkii cavendishi *Thos.*)

This small antelope with its long prehensile upper lip is a remarkable looking animal, the upper lip being constantly moved like a small trunk. They may always be found in pairs, and, during the season, the young one will remain with them until over three parts grown, after which it usually finds a mate. Their habitat is in fairly open country with small thickets where they can "lie up" during the heat of the day. They may also be found near native gardens even in cultivated steppe, where hedges of *Euphorbia tirucalli* L. provide shade for them.

Their food consists mainly of young shoots, leaves and herbs, the most favoured shrubs and trees being *Combretum parvifolium*, *Commiphora Schimperi* and *Acacia senegal* Willd. Amongst the herbs to receive preference are *Leonotis nepitifolia* Ait., *Commellina africana* L., *Asparagus Pauligulielmii* Sol. and the genus *Ipomaea*. They have frequently been observed eating sand which seems to be essential in their diet, and in their habitat may always be found places where they have been scratching.

They do not move far and may be seen daily in practically the same place, in fact a square of 200 yards will cover the beat of any pair undisturbed. Their middens may frequently be seen. These are used quite a number of times and should they be in the vicinity of a midden they will use that one. They do not drink water, sufficient moisture being obtained from plants, also from dew collected on leaves or grasses. A habit of theirs which closely resembles a habit possessed by the steinbok (*Pediotragus horstocki*) is to sink slowly to the ground until the danger has passed, and for this reason many are missed or overlooked. The writer has seen kills of dikdiks made by the following predators: lion, leopard, chita, wild dog and the martial hawk eagle. The young are born during the rains.

9. *Wart-hog* (Phacochoerus africanus aeliani *Cretzschmar*)

The favoured habitat of the wart-hog is in lightly bushed country with many small thickets where it can "lie up" during the heat of the day. Its food consists mostly of the roots of small trees and grasses. The most favoured roots of young trees are those of *Commiphora Schimperi* Engl., *C. Fischeri* Engl. and *Lannea humilis* Oliv., while, of the roots of grasses, *Panicum maximum* Jacq. and *Cypertus leucocephalus* Retz. here receive the most attention.

Water is essential and when surface water is not obtainable the wart-hog will dig for it, knowing all the most likely places. In the dry season one may be certain of finding water where it has been digging. Here, our dams are always used by them in the dry season. Frequently the holes of porcupines and antbears are used to "lie up" in during the heat of the day. They retire backwards into these and when approaching these holes it is well to be on the alert, because, on the slightest suspicion of danger they come out with a rush and the legs of unwary sportsmen have been broken when standing in front of the hole and receiving the full charge of a terrified wart-hog. They are not savage like the bush pig but possess great courage in the protection of their family.

The boar is usually solitary until the mating season, while the female with her young forms a small sounder until the next mating season and the young when over half-grown are left to themselves. The young are very active from birth and it is almost an impossibility for the average runner to catch one. When danger is scented or they are disturbed they trot away at a good pace

with their head and tail held high, in fact, the tail is almost perpendicular and rigid, the small tuft at the end moving slightly. They have a very acute sense of smell, sight ranking a poor second.

Curiosity is one of their failings: they must try and discover the cause of danger. Many times the writer has sat down within 80 yards to watch them and when seen by the male, he (the boar) has advanced to a range of 25 yards, continually advancing and retiring until the observations were finished and the writer has stood up. Of course, being in a crouching or sitting position would completely deceive them, but it undoubtedly goes to prove their curiosity.

Lions and leopards are their chief enemies, but a big boar will very often put a leopard to flight if he is able to get his tushes into action. The young are born at the commencement of the rains and onwards. Litters of ten are frequently seen.

10. *Bush pig* (Potamochoerus choiropotamus daemonis *R. Ward*)

Very little can be said of this animal owing to its nocturnal habits. Its habitat is in very dense thicket and near river beds, but it comes out to feed after sunset. It may be seen in the early morning, while on dull days it will not retire to its thicket retreat until 9 or 10 a.m. Its main food supply consists of roots, those of the young trees of *Commiphora Fischeri* Engl., *C. Schimperi* Engl., *Combretum longispicatum* Engl., *Lannea humilis* Oliv. and *Vigna triloba* Walp. being chiefly favoured by them. They are most destructive when raiding native gardens and in one night will do an enormous amount of damage, wasting and destroying all growing crops. When wounded or brought to bay, they are extremely ferocious and will charge on sight.

One morning between 9 and 10 a.m. the writer had remarkable luck in observing a huge boar rooting up earth at a remarkable pace, in search of food, while around its snout was a flock of guinea-fowl picking amongst the loose earth as it was being thrown up, the boar being quite unconcerned and allowing them within a few inches of its snout. This proves that the boar, in spite of his hasty temper, ferocity and preference for a life of solitude, is still able to manifest signs of a social instinct. When walking, the head and tail are carried low.

Lions are the chief enemies, and, for the bush-dwelling lion, the bush pig is the chief source of food. The young are born from the commencement of the rains onward, and litters of ten are frequently seen.

D. The food of seven species of ungulates tabulated (Tables 1 and 2)

In Tables 1 and 2 below are tabulated the plants seen to be eaten by giraffe, duiker, dikdik, impala, roan, kudu and eland.

The plants are collected in the following manner: either the animal is watched feeding or very fresh spoor is followed and, where the animal has

Table 1. *Plants seen to be eaten by game animals and the number of observations for each. During the season of flush (October to May)*

The abbreviations used in the tables have the following meanings: Hp. = hard-pan. El. = eluvial. Al. = alluvial. Tkt. = thicket. Hp.Tkt. = hard-pan thicket. El.Tkt. = thicket on eluvial soil. Riv. = riverine. "Mbuga" is open grassland, glade or plain, often with wooding of spindly gall-acacias. It is wet, often swampy, in the rains, and particularly dry, cracking open, in the drought. It is synonymous here with "alluvial". Tran = transition

Trees and shrubs	Native name (Kisukuma)	Habitat	Giraffe	Duiker	Dikdik	Impala	Roan	Kudu	Eland
Abrus Schimperi Hochst.	Mgagati	El.	3	—	—	2	4	9	9
Acacia Benthamii Rochebr.	Ndubilu	El. and Hp.	2	—	—	1	—	—	—
A. drepanolobium Harms.	Ilula	Hp.	5	—	—	—	—	—	—
A. Fischeri Harms.	Mhushi	Hp.	1	—	—	4	—	—	—
A. pennata Willd.	Mlatula	Hp.	1	—	—	—	—	—	—
A. senegal Willd.	Mgwata	Hp.	6	—	2	1	—	—	—
A. usambarensis Taub.	Miriwhanwhiga	Hp., Al. and Riv.	2	—	—	—	—	—	—
A. campylacantha Hochst.	Mugu	Al. and Riv.	4	—	—	—	—	—	—
Albizzia anthelmintica Brogn.	Mgada	Hp.	3	—	—	—	—	—	—
A. brachycalyx Oliv.	Mshishiguru	Hp.Tkt.	1	—	—	—	—	—	—
A. Harveyi Fourn.	Mpogora	Hp.Tkt.	13	—	—	2	—	—	1
A. sericocephala Benth.	,,	Hp.Tkt.	—	—	—	—	—	—	1
Acalypha fruticosa Forsk.	—	Hp.Tkt.	—	—	1	—	—	—	1
A. ornata Hochst.	—	Hp.Tkt.	—	—	—	1	—	2	1
Adansonia digitata L.	Mwandu	El.Tkt.	1	—	—	1 (flowers)	—	—	—
Afzelia cuanzensis Welw.	Mkola	Hp.Tkt.	—	—	—	—	—	—	3
Allophyllus grizeotomentosus Gilg.	—	Hp.Tkt.	—	—	—	—	—	1	2
Asparagus Pauligulielmii Sol.	Msauwi	Hp.Tkt.	1	1	—	2	—	1	—
Balanites aegyptiaca Del.	Myuguyu	Hp.	2	—	—	—	—	—	1
Bridelia Fischeri Pax.	—	El.Tkt.	—	—	—	1	—	—	—
Capparis tomentosa Lam.	Luwisu	Hp.Tkt.	1	—	—	1	—	—	—
Cassia goratensis Fres.	Mrundarunda	Hp.	10	—	—	—	—	2	5
Croton dichogamus Pax.	—	Hp.Tkt.	—	—	—	—	1	—	—
Cissus sp.	Mtandamwaka	El.	3	—	—	—	1	2	2
Combretum longispicatum Engl.	Linzunzu	El.	3	—	—	3	—	4	1
C. obovatum Hoffm.	Goweko	Hp. and Al.	2	—	—	2	2	—	5
C. parvifolium Engl.	Mlowashi	Hp.	10	—	—	2	1	—	1
C. splendens Engl.	Mlama	El.	4	—	—	—	—	1	—
C. ternifolium Engl. & Diels.	Mujaminzi	Al. and Hp.	1	—	—	—	—	—	—
C. trichopetalum Engl.	Lihegelya	Al.	—	—	—	—	—	2	8
C. Zeyheri Sond.	Msana	El.	—	—	—	—	—	—	1
Commiphora Fischeri Engl.	Mdonho	El.	—	—	—	—	—	—	1
C. sarandensis B. D. Burtt.	—	El.Tkt.	1	—	—	—	—	1	—

Table 1 (*cont.*)

Plants	Native name (Kisukuma)	Habitat	Giraffe	Duiker	Dikdik	Impala	Roan	Kudu	Eland
C. Schimperi Engl.	Mponda	Hp.	34	—	1	7	—	1	16
C. Stuhlmannii Engl.	Mkulungu	El.Tkt.	3	—	—	1	—	—	—
C. pilosa Engl.	Mshagashi	El.	2	—	—	—	—	—	2
C. ugogensis Engl.	Msusu	El.	1	—	—	1	—	—	—
Dalbergia melanoxylon Guil. & Per.	Mgembi	Hp.	11	—	—	3	1	1	3
D. ochracea Harms.	Mkami	Hp.Tkt.	1	—	—	—	—	—	1
D. Stuhlmannii Taub.	Fifi	El.	1	—	—	—	—	—	2
Delonix elata L.	Mtangala	El.Tkt. and Al.	5	—	—	—	—	—	—
Dichrostachys glomerata Hutch. & Dalz.	Mtundula	El. and Hp.	15	—	—	3	2	—	1
Markhamia acuminata K. Schm.	Minziigutila	El.Tkt.	11	—	—	1	—	15	10
Dombeya sp.	Msagusa	Hp.Tkt.	—	—	—	—	—	3	—
Elaeodendron Stuhlmannii Loes.	Ngakama	Al. and Tkt.	2	—	—	—	—	1	—
Fagara Merkeri Engl.	Mrungurungu	Hp.	7	—	—	—	—	1	—
Fochea Schinzii N. E. Br.	Mtembwi	Hp.Tkt.	—	—	—	—	—	—	1
Grewia bicolor Juss.	Mkoma	Hp.Tkt.	3	—	—	2	—	1	4
G. fallax K. Schm.	Mkomankuru	Al. and Tkt.	—	—	—	—	—	—	1
G. pachycalyx K. Schm.	Mperemezi	Al. and Riv.	1	—	—	3	—	—	3
G. platyclada K. Schm.	—	El.Tkt.	1	—	—	3	1	2	8
G. praecox K. Schm.	Mmendi	Hp.Tkt.	3	—	—	—	—	4	9
G. similis K. Schm.	Mdaguasa	Hp.	2	—	—	—	—	—	3
Harrisonia abyssinica Oliv.	Musomanjara	Hp. and Al.	28	—	—	1	—	4	1
Hippocratea obtusifolia Roxb.	—	Riv.	—	—	—	—	—	4	—
Hymenodictyon parvifolium Oliv.	Mchunguzi	Hp.	8	—	—	—	2	9	11
Lannea humilis Oliv.	Mtinji	Hp.	1	—	—	5	—	—	4
L. Stuhlmannii Engl.	Msyu	Hp.	1	—	—	—	1	—	1
Lonchocarpus capassa Rolf.	Mkubahubi	Al. and Riv.	1	—	—	—	—	—	1
L. eriocalyx Harms.	Mwali	El. and Hp.	4	—	—	4	—	—	1
Maerua Johannis Gilg.	—	Hp.	—	—	—	—	—	1	—
M. trichophylla Gilg.	Kidilalila	Hp.	—	—	—	—	1	1	—
Ormocarpum trichocarpum Harms.	Ilulambuli	Hp.	4	—	—	2	—	3	6
Phyllanthus Engleri Pax.	Mgogondi	El.	3	—	—	—	—	2	2
Randia Taylorii Spencer Moore	Mochangoko	Hp., Al. and Tkt.	4	—	—	—	—	—	1
Royena Fischeri Gürke & Mildbr.	Mfuwata	Hp.	—	—	—	—	1	1	7
Schrebera Kiloneura Gilg.	Mbudika	El.	1	—	—	—	1	1	1
Sclerocarya birrea var. *multifoliolata* Engl.	Mgongwa	Hp.	5	—	—	1	—	—	6 (fruits)
Srophanthus Emini Asch.	Msungulula	El.	4	—	—	—	—	—	2
Strychnos heterodoxa Gilg.	Mpandipandi	El.Tkt.	—	—	—	—	—	4	1
Sterculia triphaca R.Br.	Mhoja	El.	10	—	—	4	—	7	19
Teclea glomerata Verdoorn	Mlungusigiti	Hp.	4	—	—	—	—	—	2

Terminalia sericea Burch.	Mzima	El.	1	—	—	—	—	—	—
T. Stuhlmannii Engl.	Migiri	Hp.	11	—	—	—	—	—	—
Thespesia Garkeana Hoffm.	Mtobo	Mixed	1	—	—	—	—	—	—
Thylachium africanum Lour.	Msangwasangwa	El.Tkt.	2	—	—	—	—	1	—
Vitex Hildebrandtii Vatke.	Msungwi	El.	—	—	—	—	—	—	1
V. mombassae Vatke.	Mpuru	El.	—	—	—	—	—	1	—
Ximenia americana L.	Mtundwa	Hp.	2	—	—	—	—	1	2
Zizyphus mucronata Lam.	Mguguno	Hp.Tkt.	3	—	—	—	—	—	—

Succulent climbers and herbs	Native name (Kisukuma)	Habitat	Giraffe	Duiker	Dikdik	Impala	Roan	Kudu	Eland
Aneilema Johnstoni K. Schm.	—	Hp.Tkt.	—	—	—	—	—	—	1
Aspilia aspera	—	Mbuga	—	—	—	—	—	—	1
Berkheyopsis difusa O. Hoffm.	—	Hp.	—	—	—	—	—	—	2
Cissus Knittellii Gilg.	Kawoyawoya	Hp.	—	—	—	—	—	—	2
Commellina africana L.	Makapindepinde	Hp. and El.	—	—	—	1	3	1	20
Crotalaria laburnifolia L.	Manzigenzi	Hp. and El.	—	—	—	1	—	1	1
Dolichos pseudopachyrhysus Harms.	—	Hp. and El.	—	—	—	—	—	18	5
Hibiscus cannabinus L.	Mlaba	Mixed	5	—	—	2	—	5	8
Ipomaea Kituiensis Vatke.	Gomera	Hp.Tkt.	—	—	—	—	1	1	—
I. pilosa Sweet.	—	Al.	—	—	1	—	—	—	5
I. involucrata Beauv.	—	El.Tkt.	—	—	—	—	—	—	10
I. tomentosa	—	Al.	—	—	—	—	—	2	1
Ipomaea sp.	Likulahembi	Mixed	5	—	—	—	—	10	3
Triumfetta annua L.	—	Tkt.	—	—	—	—	—	1	—
Tephrosia sp.	—	Al.	—	—	—	—	—	1	—
Vigna triloba Walp.	Ikangabengi	Al.	3	—	—	7	—	12	15
Leonotis nepitifolia Ait.	—	Al.	—	—	1	—	—	—	2
Monechma bracteatum Hochst.	—	El.	—	—	—	—	—	1	3
Pichnostachys leptophylla Bak.	—	—	—	—	—	—	—	—	3
Sansevieria	—	—	—	—	—	12	—	—	—

Grasses	Native name	Habitat	Zebra	Roan	Impala	Eland
Aristida Steudeliana Trin. & Rupr.	—	Hp.	6	—	—	—
Blepharis acanthoides Kl.	Kuwita	Hp.	—	—	7	5
Cyperus leucocephalus Retz.	Soli	Hp.	—	—	—	—
Digitaria regularis	Bujili	Hp.	7	—	—	—
Panicum maximum Jacq.	Nyandago	Mixed	—	—	—	9
Rottboelia exaltata L.	Mabembeli	Al.	—	—	—	2
Trichopteryx simplex Hack.	Sweya	El., Hp. and Tran.	5	-	—	—

Table 2. *Plants seen to be eaten by game animals during the (dry) season of leaf-fall (June to September)*

Trees and shrubs	Native name (Kisukuma)	Habitat	Giraffe	Duiker	Dikdik	Impala	Roan	Kudu	Eland
Abrus Schimperi Hochst.	Mgagati	El.	—	—	—	6	2	9	4
Acacia Benthamii Rochebr.	Ndubilu	El. and Hp.	3	—	—	—	—	—	—
A. Fischeri Harms.	Mhushi	Hp.	12	—	—	1	—	17	—
A. pennata Willd.	Mlatula	Tkt.	1	—	1	—	—	—	—
A. senegal Willd.	Mgwata	Hp.	9	—	—	—	—	—	—
A. spirocarpa Hochst.	Magunga	Hp., Al. and Riv.	5	—	—	—	—	—	—
A. usambarensis Taub.	Miriwhanwhiga	Hp., Al. and Riv.	3	—	—	—	—	—	—
A. campylacantha Hochst.	Mugu	Al. and Riv.	6	—	—	—	—	—	—
Albizzia brachycalyx Oliv.	Mshishiguru	Tkt.	2	—	—	—	—	—	—
A. sericocephala Benth.	Mpogoro	Hp.Tkt.	4	—	—	1	—	12	4
Adansonia digitata L.	Mwandu	Tkt.	—	—	—	1 (fallen flowers)	—	1 (fallen flowers)	—
Afzelia cuanzensis Welw.	Mkola	Hp.Tkt.	—	—	—	1	—	1	—
Anisotis sp. (Burtt, No. 5144, Shinyanga)	Msagala	Tkt.	—	—	—	—	—	—	4
Balanites aegyptiaca Del.	Myuguyu	Hp.	2	—	—	3	—	—	—
Boscia pachysandra Gilg.	Msulula	Hp.Tkt.	—	—	—	—	—	4	1
Boscia sp. (Shinyanga)	Msingisa	Hp.	8	—	—	—	—	—	2
Cadaba adenotricha Gilg. & Bern.	Kaninigwa	Hp.	1	—	—	1	2	40	—
Capparis tomentosa Lam.	Luwisu	Hp.Tkt.	7	—	—	2	—	6	—
C. Kirkii Oliv.	—	Tkt.	—	—	—	—	—	20	1
Cassia goratensis Fres.	Msambila	Hp.	4	—	—	—	—	35	2
Cissus sp. (Shrub)	Mtandamwaka	El.	—	—	—	—	—	3	—
Combretum longispicatum Engl.	Linzunzu	El.	4	—	—	7	—	13	5
C. obovatum Hoffm.	Goweko	Hp. and El.	3	1	1	9	—	26	7
C. parvifolium Engl.	Mlowashi	Hp.	5	—	1	1	1	10	4
C. splendens Engl.	Mlama	El.	1	—	—	2	1	3	1
C. ternifolium Engl. & Diels.	Mujaminzi	Al. and Hp.	1	-	-	1	—	—	1
C. trichopetalum Engl.	Lihegelya	Al.	—	—	—	1	—	2	—
C. Zeyheri Sond.	Msana	El.	2	—	—	1	—	15	2
Commiphora Schimperi Engl.	Mponda	Hp.	5	—	—	4	—	1	9
C. Stuhlmannii Engl.	Mkulungu	Tkt.	—	—	—	2	—	—	—
C. pilosa Engl.	Mshagashi	El.	—	—	—	—	—	—	1
Dalbergia melanoxylon Guil. & Per.	Mgembi	Hp.	1	—	—	2	2	—	—
D. ochracea Harms.	Mkami	Tkt.	2	1	—	1	—	1	1
D. Stuhlmannii Taub.	Fifi	El.	—	—	—	—	—	2	1

Delonix elata L.	Mtangala	El.Tkt. and Al.	1	—	—	—	—	—	
Dichrostachys glomerata Hutch. & Dalz.	Mtundula	El. and Hp.	1	—	—	—	—	4	1
Markhamia acuminata K. Schm.	Minziigutila	El.Tkt.	2	—	—	3	—	18	3
M. obtusifolia Sprague	Mbapa	El.	—	—	—	2	—	—	—
Elaeodendron Stuhlmannii Loes.	Ngakama	Al.Tkt.	1	—	—	—	—	2	1
Euphorbia bilocularis N. E. Br.	—	Tkt.	4	—	—	—	—	—	
Fagara Merkeri Engl.	Mrungurungu	Hp.	2	—	1	—	—	—	2
Fochea Schinzii N. E. Br.	Mtembwi	Tkt.	—	—	—	—	—	—	2 (chewing wood for (juice
Grewia bicolor Juss.	Mkoma	Tkt.	1	—	—	3	—	—	-
G. pachycalyx K. Schm.	Mperemezi	Al. and Riv.	—	—	—	4	—	11	1
G. platyclada K. Schm.	—	El.Tkt.	—	—	1	2	—	—	1
G. praecox K. Schm.	Mmendi	Hp.Tkt.	—	—	—	1	—	1	1
Harrisonia abyssinica Oliv.	Musomanjara	Hp. and El.	15	—	3	—	1	14	—
Hippocratea obtusifolia Roxb.	—	Riv.	—	—	—	—	—	2	—
Hymenodictyon parvifolium Oliv.	Mchunguzi	Hp.	—	—	—	—	—	7	—
Lannea humilis Oliv.	Mtinji	Hp.	3	—	—	3	—	—	1
Lonchocarpus capassa Rolf.	Mkubahubi	Al. and Riv.	1	—	—	—	—	1	—
L. eriocalyx Harms.	Mwali	El. and Hp.	7	—	—	11	—	16	1
Maerua trichophylla Gilg.	Kidilalila	Hp.	—	—	—	—	—	1	2
Ormocarpum trichocarpum Harms.	Ilulambuli	Hp.	2	—	—	2	1	—	1
Ostryoderris Stuhlmannii (Taub) Dunn	Mjundu	El.	—	—	—	2	—	1	2
Phyllanthus Engleri Pax.	Mgogondi	El.	4	—	—	—	—	5	—
Randia Taylorii Spencer Moore	Mochangoko	Hp., Al. and Tkt.	1	—	—	1	1	1	—
Royena Fischeri Gürke ex Mildbr.	Mfuwata	Hp.	1	—	—	1	—	—	3
Salvadora persica Garcin	Mswaki	Hp.	—	—	—	—	—	14	—
Sclerocarya birrea Hochst. var. *multifoliolata* Engl.	Mgongwa	Hp.	—	—	—	2 (fruits)	—	1	6 (fruits)
Strychnos Burtoni Bak.	Mhundu	El.	—	1	—	—	—	—	—
S. heterodoxa Gilg.	Mpandipandi	Tkt.	—	—	—	2	—	—	—
Sterculia triphaca R. Br.	Mhoja	El.	—	—	—	1	—	—	3
Teclea glomerata Verdoorn	Mlungusigiti	Hp.	2	—	—	2	—	2	1
Terminalia serica Burch.	Mzima	El.	2	—	—	—	—	12	1
Thylachium africanum Lour.	Msangwasangwa	Tkt.	10	—	—	3	—	34	5
Ximenia americana L.	Mtundwa	Hp.	8	—	—	—	—	—	—
Zizyphus mucronata Lam.	Mguguno	Tkt.	—	—	—	1	1	—	—
Tamarindus indica L.	—	Tkt.	2	—	1	2	—	1	1

Table 2 (*cont.*)

Succulent climbers and herbs	Native name (Kisukuma)	Habitat	Giraffe	Duiker	Dikdik	Impala	Roan	Kudu	Eland
Aloe sp. (Burtt, No. 5159, Shinyanga)	-	Hp.	—	—	—	—	—	—	2 (chewing for juice)
Abutilon indicum (L.) Don.	Kawanungwa	Al. and Riv.	—	—	—		—	4	1
Asparagus Pauligulielmii Sol.	Msauwi	Tkt.	—	—	—	3	—	15	—
Cissus quadrangularis L.	Kandaga	Hp.Tkt.	1	—	—	—	—	5	—
Commellina africana L.	Makapindipindi	Hp. and El.	—	—	—	—	—	13	3
Hibiscus cannabinus L.	Mlaba	Mixed	2	—	—	—	—	7	4
Ipomaea sp. (Burtt, No. 5152)	Likulahembi	Mixed	3	—	—	—	—	1 (flower)	—
Sansevieria (Burtt, No. 5213)	—	Tkt.	—	—	—	6 (juice)	—	—	
Sarcostemma viminalis R. Br.	Mnyara ya porini	Hp.	—	—	—	2	—	8 (juice)	—
Ricinus communis L.	—	El. and Riv.	—	—	—	—	—	10	—
Grasses									
Brachiaria dictyneura Stapf.	—	El.	—	—	—	—	—	—	2
Cyperus leucocephalus Retz.	Soli	Hp.	—	—	—	2	—	—	—
Panicum maximum Jacq.	Nyandago	Mixed	—	—	—	—	2	—	—
Setaria Holstii Herm.	—	Mbuga	—	—	—	—	—	—	2
Sorghum versicolor And.	Mkia wa mbushi	Mbuga	—	—	—	—	—	—	2
Trichopteryx simplex Hack.	Sweya	El., Hp. and inter-zone	—	—	—	2	3	—	2

stopped to feed, the tree, bush or herb is scrutinized very carefully. If pieces have been freshly bitten off, a specimen is taken for identification. This is done only by the writer and his very reliable head scout.

This collection of food plants has been made to assist in describing the habitats of the seven species of ungulates mentioned in the tables. The eland prefers the open "hard-pan" country as a resting ground during the heat of the day, yet we find that most of its food supply comes from the eluvial plant communities. The impala, recognized as a grass-feeding animal, is able to adapt itself to severe dry season conditions by chewing wild *Sansevieria* to obtain moisture and eating the leaves of shrubs as a substitute for grass. Roan and zebra, definitely grass-feeding animals, occasionally eat the leaves of shrubs during the dry season. Giraffes prefer the "hard-pan" country, yet much of their food is obtained in the eluvial plant communities especially during the heavy rains when they are forced by their great weight to evacuate the soggy "hard-pan" for the higher eluvial ground. The kudu has received the most attention as regards food plants and there are no indications of its having to resort to grass as source of food. It is definitely a browser. The chief food-supply of the duiker and dikdik is from the leaves and young shoots of small trees, shrubs and herbs.

E. SUMMARY

1. "The Shinyanga Game Experiment", a contribution to the study of the intricate problem of the relations of game and tsetse, is briefly described, with maps to make the scheme clear. While the experiment is being carried out, and in so far as time and staff will allow, an investigation on ecological lines of all the local food animals of the flies will continue.

2. The local plant and animal succession is briefly described, showing how succession activated by not burning the grass is changing the habitat and forcing certain species of animals out, while for other species it is becoming more suitable.

3. A brief description is given of the habits, food and habitats of ten species of ungulates. These are as follows: giraffe, zebra, impala, roan antelope, eland, greater kudu, duiker, dikdik, wart-hog and bush pig.

4. Maps are included to illustrate the habits and movements of five species of ungulates, including a sample monthly chart showing the movements of two herds of giraffe.

5. A list of food plants is given for seven of the species of ungulates studied. The object of the collection of food plants is to assist in defining the habitats of the animals and their food habits, and the factors governing their distribution.

BIRD POPULATION STUDIES: AN ANALYSIS OF THE AVIFAUNA OF THE JEANES SCHOOL STATION, MAZABUKA, NORTHERN RHODESIA

By J. M. WINTERBOTTOM

(*With* 3 *Maps and* 6 *Figures in the Text*)

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1. Introduction

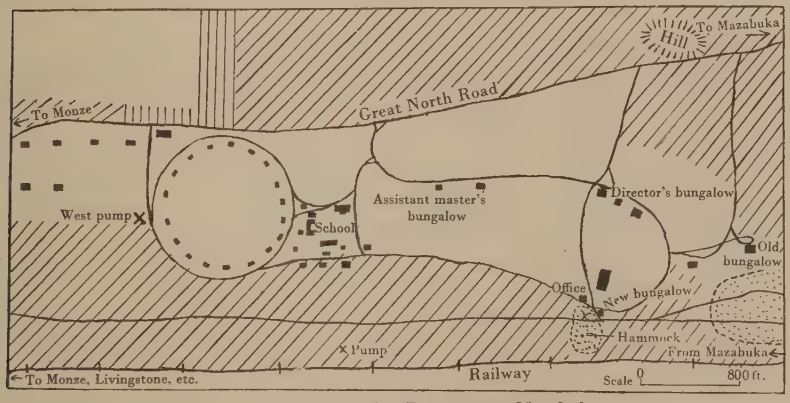
During September 1931 to June 1932 I was stationed at Mazabuka, a small town in a farming centre about 30 miles on the Livingstone side of Kafue. The Native Education Department headquarters and the Jeanes Middle and Elementary Schools are situated on a gentle slope about a mile and a half from the town, and the notes here refer only to this station and are not concerned either with the town itself or with the surrounding country.

The earlier months were naturally largely occupied in making acquaintance with the birds, but I nevertheless started sample counts (see (**6**) for an explanation of this method) in September. In the middle of November I began to supplement these by a daily list of all the species observed on the station. The value of this method has already been pointed out by Linsdale (**2**). By 29 June my list had come to include 119 species, and it is significant that one was added on each of the last 2 days. In addition, four or five species had been seen before the list was begun but were not observed later. It is particularly unfortunate that it was not possible to continue these observations for at least a further 2 months and so complete the year.

No complete counts of the station were undertaken. The advantages and disadvantages of the sample count method have already been discussed (**6**). The daily list has the same defects, but they are more pronounced. This method has been independently evolved by Linsdale (**2**, **3**), who considers it extremely valuable. It is, in any case, useful as a check on the sampling and one or two interesting features emerge from a consideration of its results. It must nevertheless be borne in mind that the two sets of figures do not measure

quite the same things and are too small to be thoroughly reliable, as is shown by the fact that when the species are listed in order of frequency, the orders of the two lists begin to diverge after the third species. All that can be considered as more or less definitely established is, therefore, that the most numerous species are *Cisticola juncidis terrestris* and *Streptopelia capicola tropica*, with *Pycnonotus t. tricolor* third.

Luckily for future workers, the Northern Rhodesia Government has set up an Ecological Survey of the botany of the territory. This work has, however, only just begun, so that until its conclusions are reported any scheme of a mere ornithologist must necessarily be regarded as extremely tentative. In its virgin condition, the Jeanes School station consists, in the main, of normal tree savannah, with, in the south-east corner, a little copse of *Acacia campylacantha*, flanked by a second, smaller clump of the same trees, among which grows a large fig, with a small wood bordering the Nakambala stream, a transitory drainage channel for the little valley to the south. The southern boundary of the station is the railway line, the northern the Great North Road (here running east and west!). Further details will more readily be seen from the accompanying map (Map 1), which shows the various buildings, roads, etc. The area of the station is about 250 acres.



Map 1. Native Education Department, Mazabuka.

Short grass, gardens, cultivation.
Long grass, with scattered, low trees.
Savannah Forest, *Acacia campylacantha* dominant.
Plantations of *Cassia Siamea*.

2. SAMPLE COUNTS

Owing to the much smaller area fewer stations could be taken than at Accra, where sample counts over any length of time would probably have been too strenuous to keep up. In all, 828 counts were taken in 10 months, distributed as follows: September 1931, 77; October, 81; November, 101;

December, 87; January 1932, 107; February, 92; March, 75; April, 80; May, 67; June, 61.

Nine stations were utilized, but at one only a single count, in June, was made. The table below (Table 1) shows the counts at the other stations. The

Table 1. *Distribution of counts according to stations*

Station	Total	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1. Old Bungalow	85	30	30	20	1	3	—	—	—	—	1
2. New Bungalow	202	—	—	12	29	30	27	26	29	26	23
3. Office	237	24	22	31	25	25	23	19	28	21	19
4. School	203	22	22	26	23	31	27	24	15	10	3
5. West Pump	22	1	3	3	7	1	2	1	—	2	2
6. A.M.'s Bungalow	16	—	2	2	2	4	1	1	—	3	1
7. Director's	21	—	2	7	—	6	2	1	—	—	3
8. Hammock	42	—	—	—	—	7	10	3	8	6	8

distribution of the centres will be seen from the map and it will be noticed that the three chief centres (1, 3, 4) in September, October and early November were well distributed, but owing to external causes, Station 1 was replaced by 2 and Station 4 declined while Station 8 rose. This was unfortunate, since 2, 3 and 8 were too close together to give an accurate picture. Perhaps the ideal arrangement would have been to have taken equal numbers of counts at Stations 1, 3, 4, 5, 7 and 8 and to have omitted Stations 2 and 6 altogether, but this was not possible. No notes on the stations will be given, since the map (Map 1) and the photographs together will give a much better idea of the place than verbal descriptions.

Altogether 78 species were included in my counts; a full list will be found in the Appendix. The following table (Table 2) gives the percentage occurrence

Table 2. *Monthly frequencies: sample counts*

Species	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1. *Cisticola juncidis*	29	40	71	83	77	81	82	78	50	49	541
2. *Streptopelia capicola*	65	59	23	41	53	63	71	65	66	80	469
3. *Pycnonotus tricolor*	44	40	40	35	32	31	29	37	51	36	306
4. *Urolestes melanoleucos*	30	26	47	44	39	27	25	26	30	23	267
5. *Mirafra fischeri*	0	12	48	55	47	48	43	7	4	25	229
6. *Tchagra senegala*	29	24	31	24	29	29	40	28	21	11	226
7. *Hirundo rustica*	0	1	31	44	69	49	23	21	3	0	221
8. *Dryoscopus cubla* and *Laniarius ferrugineus**	5	20	32	29	22	26	23	25	24	24	193
9. *Ploceus velatus*	9	22	43	23	29	25	4	0	1	13	154
10. *Dicrurus adsimilis*	21	10	6	7	6	18	25	26	18	20	123
11. *Lamprocolius chloropterus*	26	43	24	9	1	0	0	0	2	0	89

* Unfortunately, owing to a chapter of accidents, I confused these two species together soon after coming out and did not discover my error until after leaving Mazabuka.

per month of those species which reached a Credit Index (see (6) for an explanation of this term) of 3 or better in any one month. These number 11, of which *Lamprocolius chloropterus elisabeth* is conspicuous only during the first 3 months and then from the accident that it was breeding in the chimney of the bungalow I was at that time inhabiting.

If both sets of figures are reliable, the sample counts should agree with those of the daily lists fairly accurately. Comparison reveals (see Tables 2 and 3) that only in three species (*Dicrurus adsimilis*, *Dryoscopus cubla* and

Table 3. *Daily list percentages: conspicuous species*

Species	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total No. of days noted Max. 208
1. *Cisticola juncidis*	100	99	100	100	100	100	100	96	205
2. *Streptopelia capicola*	67	88	100	97	100	100	100	100	201
3. *Pycnonotus tricolor*	100	88	94	96	85	97	96	83	192
4. *Dryoscopus cubla**	100	86	81	100	85	93	100	96	191
5. *Urolestes melanoleucos*	93	90	100	100	93	77	90	87	189
6. *Tchagra senegala*	100	86	100	97	93	89	92	78	188
7. *Mirafra fischeri*	93	97	100	100	96	50	35	87	170
8. *Dicrurus adsimilis*	27	34	52	89	100	93	85	91	152
9. *Hirundo rustica*	87	83	100	100	89	83	23	0	152
10. *Uraeginthus angolensis*	14	62	36	81	78	100	82	74	145
11. *Centropus senegalensis*	33	70	94	89	78	70	46	52	144
12. *Ploceus velatus*	93	86	94	78	22	7	15	74	118
13. *Batis molitor*	13	14	61	63	70	66	58	91	117
14. *Turdoides jardinei*	13	27	42	70	74	67	69	52	113
15. *Chalcomitra senegalensis*	73	69	39	48	48	40	58	70	104
16. *Stephanibyx coronatus*	87	45	16	37	33	53	77	70	102
17. *Lybius chaplini*	—†	—†	16	70	67	73	54	65	93
18. *Circus macrourus*	60	48	74	85	67	3	0	0	91
19. *Onychognathus morio*	0	48	65	7	26	63	69	30	87
20. *Lampromorpha caprius*	60	38	57	96	66	13	0	0	86

* See note *antea*, Table 2. † Not identified; perhaps present.

Hirundo rustica) is the correspondence very close. It is clear that, in the case of very abundant species like *Cisticola juncidis terrestris* and *Streptopelia capicola tropica*, the daily list is too coarse a method to yield results of much value. But it is also clear that even an average of 83 counts per month is too few to give really reliable figures for any but the most numerous species. But let us first consider what differences we might expect to find in the two counts. Certain species, such as Abdim's stork (*Sphenorhynchus abdimii*) and the buff-backed heron (*Bubulcus ibis*) move in flocks, which wander over the countryside. They may be very numerous one day, but will have passed on the next. The same applies to passage migrants, including, at least at certain seasons, the European bee eater (*Merops apiaster*), swallow (*Hirundo r. rustica*) and swift (*Micropus a. apus*). There is at least a probability that such birds will be represented in two or three sample counts on that day; but they will, of course, be represented only once in the daily list.

On the other hand, local birds (e.g. tree-loving species such as *Oriolus auratus notatus*) will tend to be represented much more often in the daily list than in the sample counts, unless the latter include daily sample counts in their particular haunts. The first of these hypotheses probably explains a very remarkable phenomenon in the daily list figures.

In Fig. 1 are plotted the daily list figures for nine species. All show the same feature—a dip from a high figure in November to a lower one in December

and then a rise again to a higher figure in January. It is hardly conceivable that it should be a coincidence. In many cases the drop is 10% and for *Lampromorpha caprius* it is 20%. In a tenth species, *Uraeginthus angolensis niassensis*, there is a similar drop of over 20%, but it occurs a month later than in the species here referred to.

If we turn to the sample counts for confirmation, we find that in two cases the data are insufficient (*Cypsiurus parvus myochrous* and *Phylloscopus t. trochilus*), in seven there is no confirmation at all and only in two cases (*Tchagra senegala mozambica* and *Ploceus velatus tahatali*) is there any corresponding dip in the sample figures.

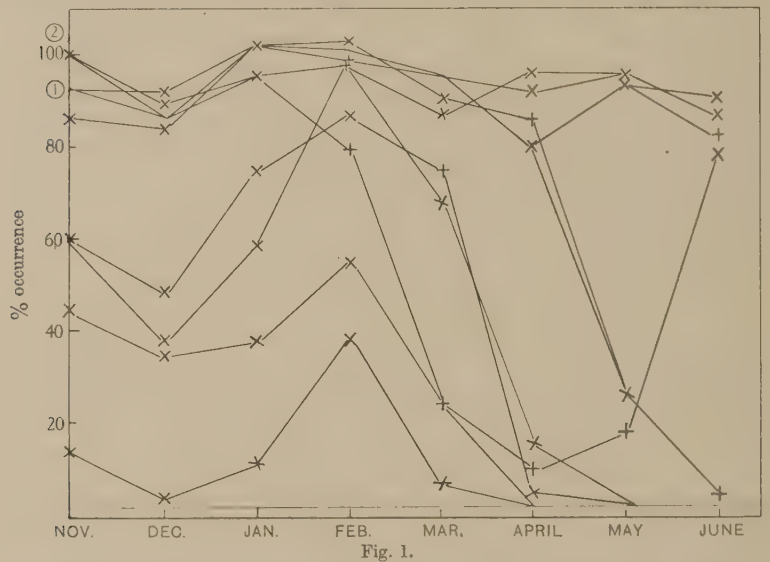


Fig. 1.

The birds exhibiting this phenomenon are a miscellaneous lot. They may be classified as under:

(1) Migrants from Europe: *Hirundo r. rustica*, *Circus macrourus*, *Phylloscopus t. trochilus*.

(2) Migrants within the Ethiopian Region: *Lampromorpha caprius*.

(3) Resident breeding species, certainly subject to local movement: *Ploceus velatus tahatali*, *Cypsiurus parvus myochrous*.

(4) Resident species not known to move regularly: *Urolestes m. melanoleucos*, *Pycnonotus t. tricolor*, *Tchagra senegala mozambica*.

They represent four orders and eight families and include raptorial, insectivorous, frugivorous and seed-eating birds. Three visit Rhodesia during their off season, one in its breeding season; two certainly, one probably and a fourth possibly actually bred on the station *during the time referred to*.

I am inclined to dismiss the case of *Urolestes melanoleucos*. The station supported three birds of this species all the time I was there, but its 250 acres were not sufficient for their entire support. Wandering farther afield to feed young (the species bred on the station) may account for the drop, which is, in any case, very slight.

Cypsiurus parvus does not breed on the station, but probably does so some miles away at Nanga palms, on the edge of the Kafue Flats. The evidence points to April onwards as its breeding time, since from that date it disappears (actually, the last record for the station is April 4, previous to which none had been seen for over a fortnight). I can think of no explanation to cover the case of this bird, unless it is afflicted with a kind of *wanderlust* during December!

Pycnonotus tricolor, *Tchagra senegala* and *Ploceus velatus* may have been busy incubating. The two latter are also less conspicuous in the sample counts at this time. *Ploceus* had three nesting colonies on the station and two others just over the borders, one to the north and one to the south.

This leaves us with the four migrant species and it is here that I think the differences between the two types of count are significant. Let us take the swallow (*H. r. rustica*) as an example. The bird winters all over Africa from the Gold Coast to the Union. In Rhodesia, Pitman has observed a few swallows as early as the last week in September, but the bulk of the swallows do not arrive until the rains set in. Indeed, they arrive *with* the rain, as do the swifts (*Micropus a. apus*). The swifts pass on in a body, although further parties may appear later. My suggestion is that these first swallows merely pause awhile in Rhodesia and then pass on southwards in December, being replaced by others from farther north, which represent the resident birds in January and February. It had also occurred to me that there might, perhaps, be a "back wash" of migrants from the south, but I had abandoned this idea as too far fetched when it received unexpected confirmation. on phenological grounds, from the observations of Mr H. H. Parker in the Union of South Africa (**4**).

My own observations on bee-eaters and swallows at Fort Jameson also support this interpretation that many migrants may at first proceed far to the south and subsequently work north again. In this way, the passage birds, which would rest and feed during the day at Mazabuka, would be abundant on those days they were there and the species would thus be better represented in the sample counts than it would be by the fewer, temporarily resident swallows of November. But in the daily list, the days that no swallows rested at Mazabuka would outweigh their abundance on the days on which they did remain. The northward migratory movement (not the "backwash") which has begun by the end of February at the latest, is more gradual and is, as far as my observations suggest, conducted in smaller parties than the southern flighting. It would thus not affect the two sets of figures differentially. Much the same argument applies to the other species.

3. Effect of seasons

Examination of Tables 2 and 3 and Figs. 2, 3 and 4 show that for most species, the maximum abundance occurs some time during the rains (November to April) and this is what might be expected. But for two species, *Mirafra fischeri zombae* and *Ploceus velatus tahatali*, there is a second maximum after the rains, in June (and perhaps July). This is interesting and needs explanation.

In the case of *Mirafra*, I think the actual figures are illusory but none the less instructive. The birds of this genus are known as "flappet-larks" from

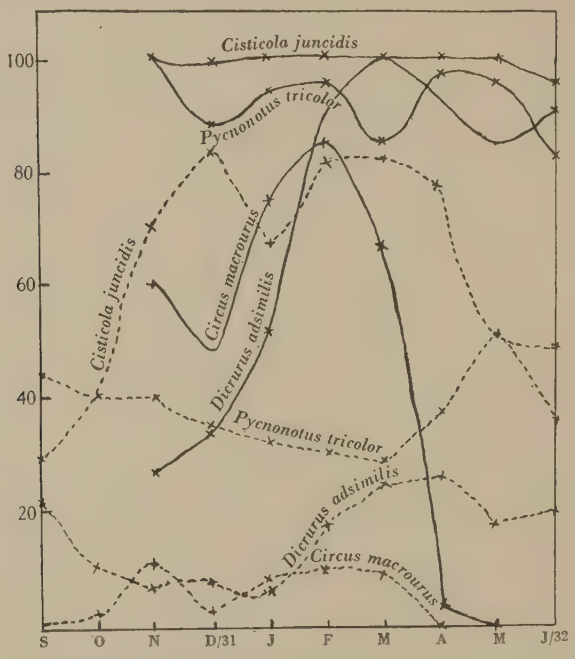


Fig. 2. Daily list: whole. Sample counts: dotted.

their habit of beating with the wings, making a sound which has been likened to castanets. I had already encountered one species (*M. buckleyi*) in the Gold Coast and had there ascertained that its noise is a true song, in that it has territorial significance. Bates' (**1**) remark of this species that "for once it is seen on the ground, it will be ten times seen or heard in the air," is equally true of *M. fischeri* and although it utters a characteristic two-syllable call on the ground, it is its flappetting that is the really conspicuous thing about it. During the rains, this bird flappets incessantly. By April this has almost stopped, but in June, after the rains and breeding are over, it has a second

period of flappetting, which I can only compare to the autumn song-period of many Palaearctic birds (including, be it noted, *Phylloscopus trochilus* in winter quarters). This is the explanation of the second maximum in this species.

With *Ploceus velatus*, however, things are different. Breeding finishes in February and the birds disappear from the station. In this case, I am convinced, they really do disappear. They go off to join their relatives and the

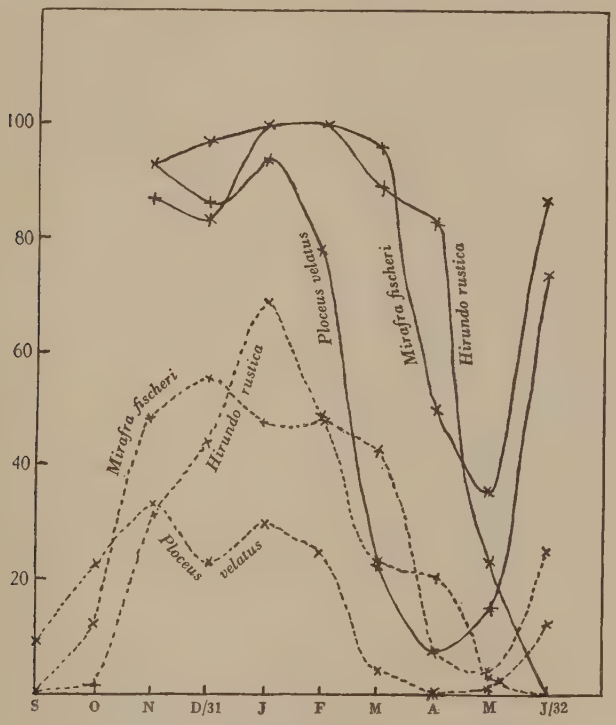


Fig. 3. Daily list: whole. Sample counts: dotted.

finches in an attack on the ripening Kaffir corn or sorghum of the natives. So serious is this attack, that it is only by constant bird scaring that the natives can reap a harvest at all. Clouds of Ploceid and Fringillid birds descend upon the crops and they are a far more serious, because more constant, danger than locusts. But by June, the bulk of the harvest is in and the birds return to devour the seeds of the grasses on open dambos and elsewhere. This is the second maximum.

Local movement is also exhibited by the crowned lapwing (*Stephanibyx coronatus*), which was uncommon on the station during January, February and

March. It probably repairs to the great swampy areas on the Kafue Flats at this season. The bronze-winged courser (*Rhinoptilus chalcopterus albofasciatus*) also exhibits local movement. From late May or early June onwards I saw examples a number of times on or near the station, but during the rains it disappears no man knows whither.

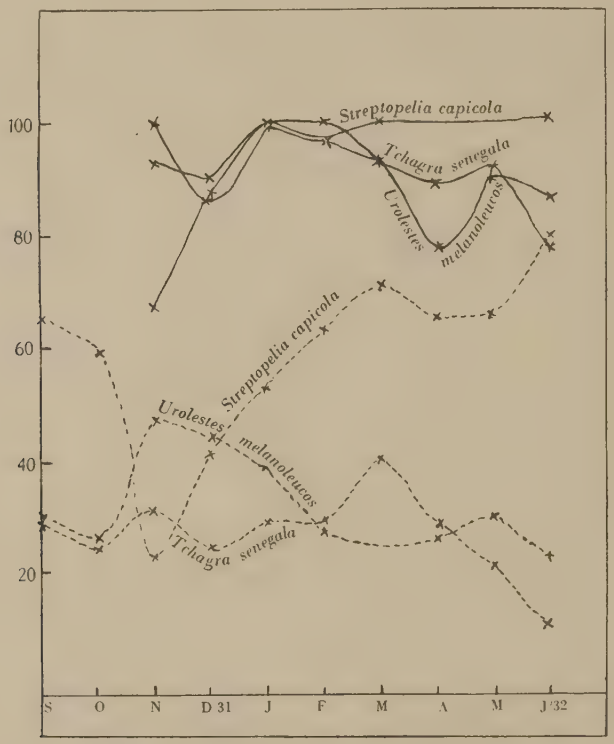


Fig. 4. Daily list: whole. Sample counts: dotted.

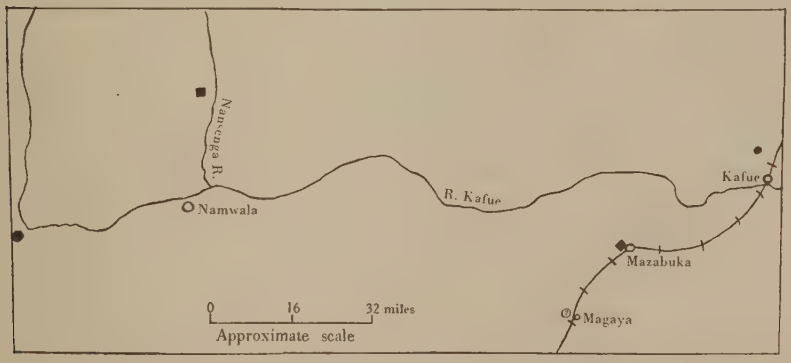
4. Less common birds

From the text and tables, the relative abundance and the identity of the common species can readily be made out, but a few words about the less numerous, but nevertheless frequently observed species might not be out of place.

Of these, by far the most interesting is Chaplin's barbet (*Lybius chaplini*). The daily list percentages for this bird are:

November and December, 0; January, 16; February, 70; March, 67; April, 73; May, 54; June, 65.

This is enough to indicate that, at times at least, it is a conspicuous species at Mazabuka. Yet this bird was for 10 years known only from a single specimen; not until 1931, when Pitman got five more (see **2**), could it be decided definitely whether this was a good species or just a freak. I noted it first on 30 August, a few days after my arrival in the Territory and my last record was on 29 June, the day I left. Between 16 November 1931 and 29 June 1932, I saw or heard it on the station on 93 separate days, and the six specimens I obtained for the British Museum have doubled the number of known examples. Incidentally, while the first six specimens all came from "far far bush", my six were all shot within 20 yards of the railway line, beside which I have reason to believe this barbet breeds! The map (Map 2) shows the known distribution of this species.



Map 2. Distribution of Chaplin's Barbet (*Lybius chaplini*).

● Approximate locality of original specimen. ■ Five specimens obtained by Capt. C. R. S. Pitman. ◆ Six specimens obtained by J. M. Winterbottom. ⑦ One doubtfully identified by Capt. C. R. S. Pitman.

Chaplin's barbet is frugivorous. When the wild figs are ripe, it joins what may be called the "fig association", which includes also the green pigeon (*Vinago delalandii orientalis*), the speckled coly (*Colius striatus berlepschi*) and the black-collared barbet (*Lybius torquatus congicus*). I have never seen any of these birds far away from fig-trees, though *L. chaplini* and the coly do not seem subject to the extensive local movements that the other two species undertake and must therefore have other food supplies (see also (**5**) and (**7**)).

The most specialized of the four fig-birds is the green pigeon. During January and February, when the big fig-tree already referred to was in full fruit, I saw and shot several. Thereafter it disappeared.

Lybius torquatus was also most abundant in January, although never really numerous. After 22 March, it was not noted on the station until 16 June, when it was heard once more. Some time between the end of June and the beginning of September, it must return.

Another species which at times frequents the fig-trees is the red-winged starling (*Onychognathus m. morio*). At Livingstone, in the gorges below the Victoria Falls, it is very numerous on trees of this family, but I did not notice it in this connexion at Mazabuka. Indeed, it is a little surprising to find it there at all, for the species is normally a lover of rocky places.

Its relative abundance is shown by the following daily list percentages: November, 0; December, 48; January, 65; February, 7; March, 26; April, 63; May, 70; June, 30. The double maximum, in January and May, suggests passage, which is confirmed by the way in which the entries occur: 21 December - 16 January inclusive (for two of these days I was absent from the station); 1–14 April inclusive; 9–23 May except 16th and 17th; 25–29 June; with scattered records in between.

The African barn-owl (*Tyto alba affinis*) bred on the station and was heard most often between February and May. On 11 June, a parent and two partially fledged young were evicted from the office roof.

The little chin-spot flycatcher (*Batis m. molitor*) was often heard in the trees round the "Hammock" and "New Bungalow" stations. Daily list percentages: November, 13; December, 14; January, 61; February, 63; March, 70; April, 67; May, 58; June, 91. This, incidentally, is another bimaximal curve.

The Senegal coucal (*Centropus senegalensis flecki*) is a species more often heard than seen, for it keeps to cover and long grass. Percentages (daily list): November, 33; December, 65; January, 93; February, 89; March, 78; April, 70; May, 46; June, 52. I am unable to give any sound reason for the variation in this curve. The coucal normally calls at dusk and at dawn; whether I heard it less in May because there were fewer birds to hear or because, as seems more likely, those present called less, I do not know.

Of the sunbirds, the scarlet-chested *Chalcomitra senegalensis gutteralis* was the commonest. The percentages for this bird are: November, 73; December, 42; January, 39; February, 48; March, 48; April, 40; May, 58; June, 70. This suggests that the scarlet-chested sunbird is more numerous in the dry season than in the rains, which is unusual.

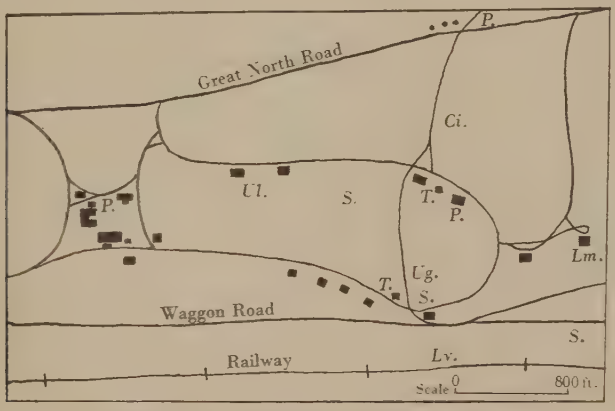
The grey hornbill (*Lophocerus nasutus epirhinus*) was a not uncommon visitor, being observed on 85 out of the 208 days, and most frequently in January (61 %). It visited the trees of *Acacia campylacantha*, the seeds of which it eats.

Reference has already been made to the crowned lapwing (*Stephanibyx coronatus*) for which daily list percentages are: November, 87; December, 45; January, 16; February, 37; March, 33; April, 53; May, 77; June, 70.

Parties of arrow-marked and, more rarely, white-rumped babblers (*Turdoides jardinei jardinei kirki*[1] and *T. leucopygia hartlaubi*) were both seen and heard fairly often, but the relations of the two species were not worked out. Babblers were noted on 113 days out of the 208.

[1] Intermediates between the two races.

Besides the abundant *Streptopelia capicola tropica*, two other turtle-doves were noted. The big *S. s. semitorquata* was seen on 52 days and was most numerous in April (80 %); I believe it to be subject to local movement. *Stigmatopelia senegalensis aequatorialis* was identified on 45 days, chiefly in April, May and June, when its curious "laugh" was often heard. But it was undoubtedly present in the district, and probably on the station, all the time I was there. Its resemblance to the much commoner *S. capicola*, however, made it very difficult to detect and it must frequently have been overlooked. The long-tailed dove (*Oena c. capensis*) was the only other pigeon noted at all frequently (38 days, maximum in June).



Map 3. Native Education Department: nests.

Ci. = *Cisticola juncidis*; *Lm.* = *Lamprocolius chloropterus*; *Ly.* = *Lybius chaplini*; *P.* = *Ploceus velatus* (colonies); *S.* = *Streptopelia capicola*; *T.* = *Tyto alba*; *Ug.* = *Uraeginthus angolensis*; *Ul.* = *Urolestes melanoleucos*.

Merops apiaster was not uncommon on passage in March and April (I arrived rather too late for the autumnal passage in 1931), when one or more flocks were noted passing over on 28 separate days. The hoopoe (*Upupa africana*) appeared in June, when examples were noted on 10 of the 23 days I was on the station. *Oriolus auratus notatus* was another migrant that appeared after the rains. *Lanius collurio*, a passage migrant, was observed between February and April, chiefly in the latter month. The bateleur (*Terathopius ecaudatus*) occurred on 64 days, pretty generally distributed over the period under review.

5. Seasonal figures

In Table 4 will be seen the average number of species per count per month for the sample counts and the average number of species per day per month for the daily lists. It will be seen that the fauna is richest in species during the

rains, especially in February. This is in some considerable measure accounted for by the migrants from the north, particularly from Europe. Besides the species already referred to, the spotted flycatcher (*Muscicapa s. striata*) occurred on 44 days and the house-martin (*Delichon urbica*), sand-martin (*Riparia r. riparia*), swift (*Micropus a. apus*), cuckoo (*Cuculus canorus*), red-footed falcon (*Falco amurensis*) and white stork (*Ciconia c. ciconia*) were noted a few times.

Table 4. *Number of species per unit per month*

Type	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Unit
Sample counts	3·5	4·1	5·3	5·2	5·5	6·6	4·7	4·0	4·1	4·3	Species per count
Daily lists	—	—	17·0	17·9	21·2	25·3	21·0	20·2	18·1	20·3	Species per day

It will, however, be noticed that by far the most conspicuous of these birds is the swallow (*Hirundo r. rustica*), which is, from November to April, one of the most numerous birds on the station. On the Gold Coast, I found (**4**) that while the European swallow was an extremely numerous species in the forest country, it was rare in the savannah, and I suggested that food supply was the limiting factor which drove it into the forest, but that it was nesting sites that kept it from breeding there. Now in Rhodesia, in savannah country, the swallow turns out to be a very numerous bird (my travel counts, which will be published elsewhere, support this conclusion). This, at first, seems to knock the bottom out of my previous theory, but there is really no difficulty in reconciling the two sets of facts. The important point is that whereas the European migrants visit the Gold Coast in the *dry* season, they come to Rhodesia in the *rains*. Moreover, it will be found that the same holds good for most of the migrants from within the Ethiopian region. *Bubulcus ibis*, *Milvus migrans parasitus*, *Melittophagus p. pusillus* and *Aerops albicollis* are dry season visitors to the Gold Coast Colony and Ashanti. But *Lampromorpha caprius*, the various species of *Clamator*, *Milvus migrans parasitus*, *Coracias c. caudatus* and *Sphenorhynchus abdimii* are wet season migrants to Northern Rhodesia. The dry season visitors, like *Rhinoptilus chalcopterus albofasciatus*, *Upupa africana* and *Oriolus auratus notatus*, are much less conspicuous and play a far smaller part in the economy of the country.

If we compare these figures with those of Linsdale for Kansas (**2**). the results are suggestive. The maximum (daily list) for this American area is in May (124), with a second maximum in September (121). These are presumably the months of the spring and autumn passage rushes. At Mazabuka, passage is a more spread-out affair, beginning with the bee-eaters in September and not finishing until after the rains have set in in November. For the eight months there, the maximum comes in February, with 72 species. At this period all the visitors have arrived and the northward flow has begun to draw the passage migrants from the south. January (69), April (65) and June (58) are next. The

minimum, which in Kansas is in December (34), in Rhodesia seems to be in November (39), but only 15 days were considered in November, at which time identification was still a large problem. Fig. 5 expresses these figures graphically.

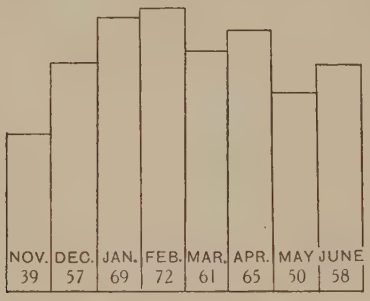


Fig. 5. Species per month.

6. Some comparative results

As compared with the Gold Coast (Accra), we see that this Northern Rhodesian station is a little less severe an environment. In six weeks in Accra, 35 species occur in the sample counts; the average monthly figure for Mazabuka is 36·6. Three species in Accra have a Credit Index of 1 or 2; five Mazabuka species, *Streptopelia capicola tropica*, *Cisticola juncidis terrestris*, *Hirundo rustica rustica*, *Mirafra fischeri zombae* and *Pycnonotus tricolor tricolor* achieve such an index for one or more months. In Accra, two species have Credit Indices of 1 for the whole six weeks, but only the first two Rhodesian species named above obtain an index of 2 on the whole series: out of 78 species represented, only 11 occur in more than one-eighth of the total number of counts, while 16 are represented by a single occurrence and 7 more by two occurrences. This once more emphasizes that in a natural environment far more species can exist side by side than in a man-made environment. Table 5

Table 5. *Sample counts: comparative figures*

Place	Duration of count	Av. No. of species per month	No. of species with C.I. 1 in any month	No. of species with C.I. 2. in any month	No. of species with C.I. 1 or 2 on whole count	No. of species with C.I. 1, 2 or 3 on whole count
Ipswich, England	3 months	18·7	3	1	3	5
Swiss villages	3 weeks	37	2	8	10	11
Accra, G.C.	6 weeks	35*	2*	1*	3*	11*
Mazabuka, N. R.	10 months	36·6	2	3	2	11

* Six weeks.

gives comparative figures from a moderately closely settled English town (Ipswich); a miscellaneous group of Swiss villages; an open town in the equatorial African savannah, of the type which corresponds to an English

"Garden City" (Accra); and a scattered station in tropical African savannah (Jeanes School, Mazabuka). It must be remembered that no very strict comparisons should be drawn between the European and the African places in view of the great climatic and faunistic differences that obtain. But the much

Table 6. *Daily list Raunkaier groups: Rhodesia and America*

Country	A	B	C	D	E
Northern Rhodesia	75	7	9	3	6
Kansas, N. America	68	16	7	3	5
California, N. America	73	13	5	3	5

Note. Figures are percentages.

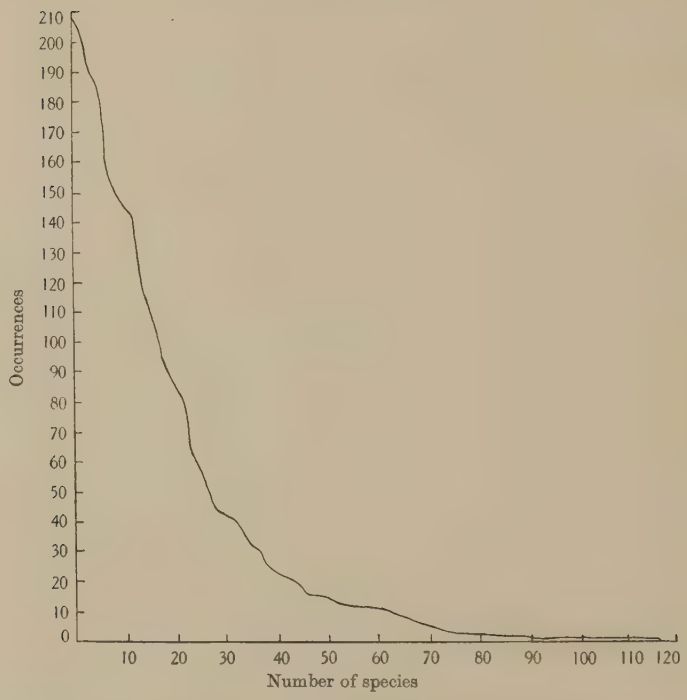


Fig. 6. Relative frequency of occurrence: daily list, Mazabuka.

greater relative density of the European birds, as indicated by the fact that no less than 10 species occur in column V for Switzerland, is worth noting. It is also instructive to notice that there seems to be an absence of "moderately common" (Credit Index 3) species in temperate regions—2 for Ipswich and 1 for Switzerland; whereas there is a much more even gradation in the tropics—8 for the Gold Coast and 9 for Rhodesia (see also below, Table 6). In Europe, the majority of species, at least round human habitations, seem to be either

definitely common or definitely uncommon, but in tropical Africa there is more room for the less dominant species to find a living.

Linsdale (**2**, **3**) has pointed out that frequencies in birds may obey the same laws as frequencies in plants. She divided her species into groups on the following basis, originated by Raunkaier for plants: group A, birds which occur in 1–20 % of the days on which observations were made; group B, birds occurring in 21–40 %; group C, in 41 60 %; group D, in 61–80 %; group E, in 81–100 %. And she found, as has already been shown to obtain for plants, a relation such that $A > B > C \gtrless D < E$. [1]Table 6 shows the Mazabuka daily list figures treated in this way, with Linsdale's figures for comparison. It will be noted that the African figures differ seriously from the expected formula in respect of groups B and C. Unfortunately, I have no comparable English figures: but the present ones confirm the conclusions drawn from the sample census figures above, that there is a difference in kind between bird numbers in the tropics and in temperate regions.

7. SUMMARY

Sample counts and daily frequencies were worked out for the birds at a station in Northern Rhodesia, from September 1931 to June 1932. 118 species were observed, showing in many cases marked seasonal variations in relative abundance, partly due to migration. Notes are given on the breeding, habitats, and movements of certain species.

APPENDIX

Alphabetical list of all species observed

Species	No. of days in daily list	No. of times in sample counts
1. *Alseonax adustus subadustus* Shell.	2	1
2. *Anthreptes collaris ugandae* v. Som.	14	5
3. *Anthus richardi raaltoni* Layard	44	16
4. *Aquila wahlbergi* Sund.	22	15
5. *Ardea cinerea cinerea* L.	1	0
6. *A. goliath* Cretsch.	1	0
7. *Astur* spp. (including *Melierax gabar*)	31	10
8. *Balearica regulorum regulorum* (Benn.)	3	4
9. *Batis molitor molitor* (Hahn & Künst.)	117	37
10. *Bubo africanus africanus* (Temm.)	5	0
11. *Bubulcus ibis* (L.)	15	9
12. *Burhinus capensis capensis* (Licht.)	1	0
13. *Buteo rufofuscus augur* (Rüpp.)	11	2
14. *Bycanistes buccinator* (Temm.)	1	0
15. *Caprimulgus fossei fossei* Hartl.	24	0
16. *Centropus senegalensis flecki* Rchw.	114	92
17. *Ciconia ciconia ciconia* (L.)	1	0
18. *Cinnyricinclus leucogaster verreauxi* (Boc.)	1	0

[1] I hesitate to follow Linsdale in the rather sweeping claims she makes for the present method. Raunkaier's formula has been adversely criticized (see *Nature*, **132**, 1933, pp. 864–65).

	Species	No. of days in daily list	No. of times in sample counts
19.	*Cinnyris chalybeus ludovicensis* (Boc.)	11	1
20.	*Chalcomitra senegalensis gutteralis* (L.)	104	70
21.	*Circus macrourus* (Gmel.)	91	39
22.	*Cisticola aridula lobito* Lynes	1	0
23.	*C. juncidis terrestris* (Smith)	205	541
24.	*Clamator* sp.	2	1
25.	*Colius striatus berlepschi* Hartert	44	3
26.	*Coliuspasser albonotatus albonotatus* (Cass.)	3	0
27.	*C. macrourus macrourus* (Gmel.)	4	0
28.	*Coracias caudatus caudatus* L.	51	24
29.	*Corvus albus* Müll.	14	10
30.	*Cosmetornis vexillarus* (Gould)	2	0
31.	*Cossypha heuglini subrufescens* Boc.	4	0
32.	*Coturnix delegorguei* Deleg.	1	0
33.	*Crinifer concolor concolor* (Smith)	11	2
34.	*Cuculus canorus* subsp.	1	0
35.	*Cuncuma vocifer* (Daud.)	1	0
36.	*Cursorius temminckii temminckii* Swains.	0	1
37.	*Cypsiurus parvus myochrous* Rchw.	52	17
38.	*Delichon urbica* (L.)	2	0
39.	*Dicrurus adsimilis divaricatus* (Licht.)	152	123
40.	*Dryoscopus cubla hamatus* Hartl. and *Laniarius ferrugineus mossambicus* (Rchw.)	191	193
41.	*Elanus caeruleus caeruleus* Defres.	28	1
42.	*Eremomela griseoflava griseoflava* Sharpe	1	0
43.	*Eremopteryx leucotis smithi* Bp.	1	0
44.	*Euplectes capensis sabinjo* Rchw.	23	1
45.	*E. hordeacea hordeacea* (L.)	1	0
46.	*Falco amurensis* Radde	2	0
47.	*F. dickinsoni* Scl.	2	0
48.	*Francolinus coqui coqui* (Smith)	41	8
49.	*Glareola pratincola fulleborni* Neum.	3	1
50.	*Halcyon chelicuti chelicuti* (Stanley)	16	18
51.	*H. leucocephala swainsoni* Smith	61	14
52.	*Hirundo rustica rustica* L.	152	221
53.	*H. senegalensis monteiri* Hartl.	15	8
54.	*Hypochaera amauropteryx* Sharpe	3	0
55.	*Indicator indicator* (Sparrm.)	2	1
56.	*Lagonosticta senegala rendalli* Hart.	13	5
57.	*Lamprocolius chloropterus elisabeth* Stresem.	23	89
58.	*Lampromorpha caprius* (Bodd.)	86	39
59.	*Lanius collurio* L.	12	1
60.	*Leptoptilus crumeniferus* (Less.)	1	0
61.	*Lissotis melanogaster* (Rüpp.)	16	6
62.	*Lophocerus nasutus epirhinus* (Sund.)	85	45
63.	*Lybius chaplini* Clarke	93	28
64.	*L. torquatus congicus* Rchw.	30	28
65.	*Macronyx croceus croceus* (Vieill.)	11	21
66.	*Melittophagus bullockoides* (Smith)	3	0
67.	*M. pusillus meridionalis* Sharpe	27	5
68.	*Merops apiaster* L.	33	1
69.	*M. superciliosus* L. ?	1	0
70.	*Micropus apus apus* (L.)	7	9
71.	*Milvus migrans parasitus* (Daud.)	21	37
72.	*Mirafra fischeri zombae* O. Grant	170	229
73.	*Muscicapa striata striata* (Pall.)	44	22
74.	*Oena capensis capensis* (L.)	38	23
75.	*Oenanthe pileata livingstonei* (Tristram)	3	0
76.	*Onychognathus morio morio* (L.)	87	26
77.	*Oriolus auratus notatus* Peters	9	2
78.	*Parus rufiventris rufiventris* Boc.	2	0
79.	*Petronia superciliaris* (Blyth)	1	0
80.	*Phylloscopus trochilus trochilus* (L.)	19	7
81.	*Plectropterus gambensis gambensis* (L.)	8	0
82.	*Ploceus velatus tahatali* Smith	118	154

Species	No. of days in daily list	No. of times in sample counts
83. *Pogoniulus chrysoconus rhodesiae* C. Grant	1	0
84. *Poicephalus ? robustus suahelicus* Rchw.	1	0
85. *Poliospiza gularis reichardi* Rchw.	1	0
86. *Polomaëtus bellicosus* (Daud.)	1	0
87. *Prinia mistacea graueri* Hart.	13	5
88. *Pternistes swainsoni* Smith	16	4
89. *Pycnonotus tricolor tricolor* (Hartl.)	192	306
90. *Rhinoptilus chalcopterus albofasciatus* Sharpe	1	0
91. *Riparia cincta cincta* (Bodd.)	13	3
92. *R. riparia riparia* (L.)	3	1
93. *Sarkidiornis melanotus* (Pennant)	4	1
94. *Saxicola torquata robusta* (Tristram)	1	0
95. *Scopus umbretta bannermani* C. Grant	1	0
96. *Serinus mozambicus mozambicus* (Müll.)	8	0
97. *S. sulphuratus shelleyi* Neum.	31	6
98. *Sphenorhynchus abdimii* (Licht.)	16	13
99. *Stephanibyx coronatus* (Bodd.)	102	48
100. *Streptopelia capicola tropica* (Rchw.)	201	469
101. *S. semitorquata semitorquata* (Rüpp.)	52	17
102. *S. senegalensis aequatorialis* (Erl.)	45	21
103. *Strix woodfordi woodfordi* (Smith)	5	0
104. *Tchagra australis congener* (Rchw.)	1	0
105. *T. senegala mozambica* (v. Som.)	188	226
106. *Tchitrea perspicillata plumbeiceps* (Rchw.)	13	10
107. *Terathopius ecaudatus* (Daud.)	64	23
108. *Thamnolaea arnotti collaris* (Rchw.)	3	0
109. *Torgos tracheliotus* (Forst.)	9	2
110. *Turdoides jardinei jardinei* $\gtrless$ *kirki* and *T. leucopygia hartlaubi* (Boc.)	113	50
111. *Turdus libonyanus niassae* Rensch.	0	1
112. *Tyto alba affinis* (Blyth)	83	0
113. *Upupa africana* Bechst.	7	2
114. *Uraeginthus angolensis niassensis* Rchw.	145	71
115. *Urolestes melanoleucos melanoleucos* (Jard.)	189	267
116. *Vidua macroura* (Pall.)	6	2
117. *Vinago delalandii orientalis* Gunn. & Robts.	9	1
118. *Xiphidiopterus albiceps* (Gould)	1	1

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THE BIRD POPULATION OF AN AREA IN SUSSEX

By VERA MAYNARD

(*With* 1 *Map in the Text*)

A census of nesting birds on an area of approximately 20 acres at Woodwards, Burgess Hill, Sussex, was done in 1934, and repeated in 1935. The following condensed notes contain a description of the area with rainfall figures, the numbers of nests and their sites, together with observations on nesting times, and the relative abundance of different species throughout the year.

Area. Pasture fields, used for hay; grazing of young stock and occasionally sheep. Field *B*, a portion of this now has houses and gardens upon it. Until 12 years ago it had always been an arable field.

Height. 210 ft. above sea-level.

Soil. All Weald Clay. This stretches approximately 4 miles east and west of the area, and 1 mile north and south.

Water. Only a tiny brook on the south side—an outlet from a pond.

Hedges. These are marked as lines on the map. They are of an almost uniform height of 4 ft., and the width varies from $1\frac{1}{4}$ to 2 yd.; average width being $1\frac{1}{2}$ yd. The foundation of the hedges is hawthorn (*Crataegus* sp.), with a sprinkling of bramble (*Rubus* sp.), dog rose (*Rosa* sp.), and blackthorn (*Prunus spinosa*). Field *D*, however, has a foundation of blackthorn on the north and west, while field *E* has a south hedge composed of bramble and tiny saplings behind the ditch—saplings too small to indicate on the map.

Trees. Chiefly oak (*Quercus robur*) and ash (*Fraxinus excelsior*). All marked on the map.

Boundaries. North: Burgess Hill, $\frac{1}{2}$ mile along a residential road. A town with a population of 6000. South: Fields, small woods, cattle ponds, a few houses and gardens to the village of Keymer. The South Downs are a mile beyond. East: Houses and gardens border the road, otherwise fields for 1 mile to Ditchling Common—an open space with a fair sized pond, and bordered with thick undergrowths and fields, trees and woods. West: Two private properties of approximately 30 acres. One contains spinneys, a small pond, and a rookery of about forty nests. Then comes the main line of the Southern Railway.

Map. The area not investigated is hatched. This part of the map shows where new houses and gardens have been built during the last 5–8 years. Woodwards house and garden are 10 years old. The acreage of the fields is given.

Ringing. A Potter trap was used in the verandah and on the lawn during the months of February and March 1935. The result was as follows:

Blue tits	78	Hedge sparrows	3
Great tits	48	Song thrushes	2
Marsh tits	6	Blackbird (hen)	1
Coal tits	7	Redbreasts	4
Nuthatch	1	Starlings	3
Greenfinch	1		

It was noticeable that great and blue tits were mainly non-residents, unringed ones coming to feed in batches about every 5 days. The marsh and coal tits, however, were resident in the neighbourhood (proved by retrapping; they came here again in November 1935). The trap was used occasionally throughout the year.

Food. A bird table is in the verandah for scraps, fat, and nuts. A nut hopper is attached to an upstairs window. Oatmeal and crumbs are placed on the floor of the verandah. A bird bath on the lawn.

Rainfall (in inches) taken by the local Water Company from January 1934 to 30th November 1935, with their observations.

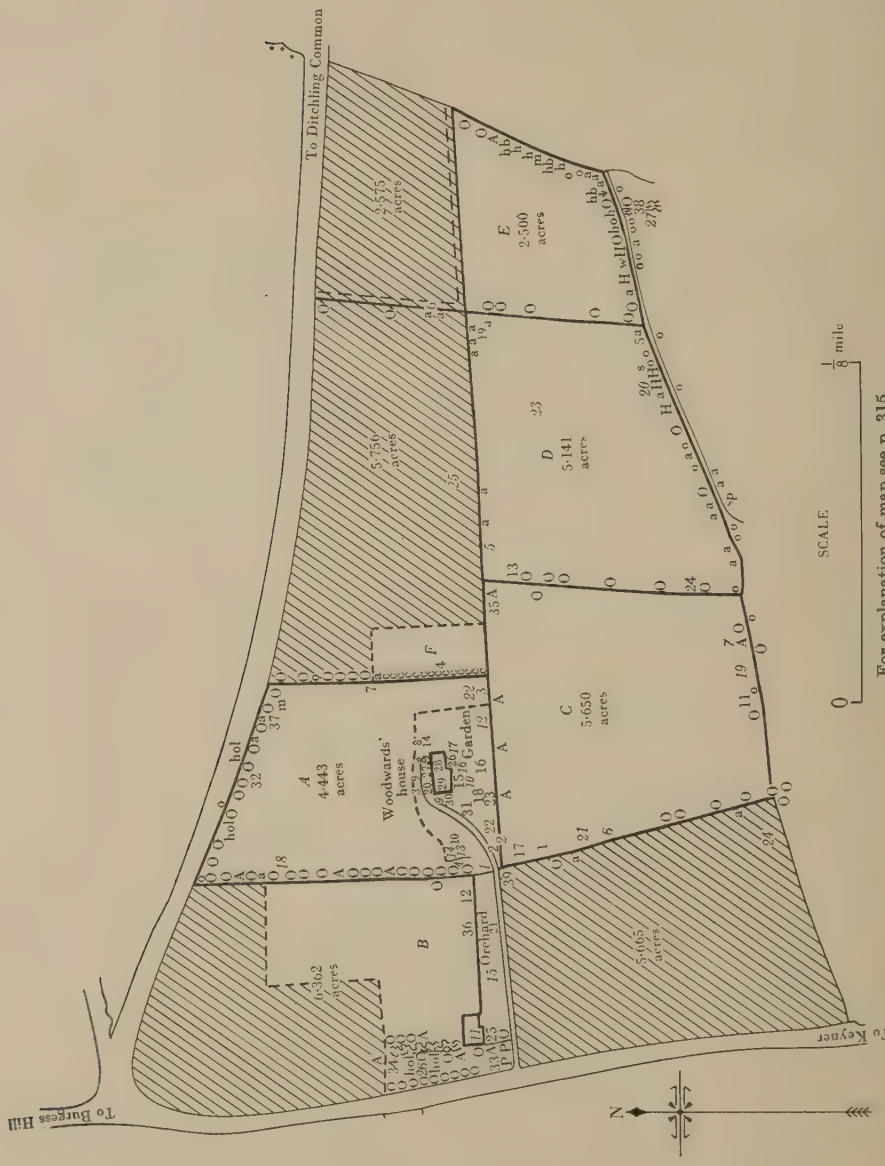
Jan. 3·45. All fell in week ending 3rd.
Feb. 0·8. Dry and frosty.
Mar. 3·52. Chiefly fell during week ending 17th.
Apr. 3·50. Fair. Heavy rain week ending 28th.
May 0·46. Showery, then dry and fine.
June 1·73.
July 1·72.
Aug. 2·82. Chiefly during one week ending 29th.
Sept. 2·62.
Oct. 2·80. Week ending 6th, a wet spell of 2·10.
Nov. 6·35. Main fall on isolated days.
Dec. 12·48. Very wet. Week ending 8th, 4·05 fell in 6 days.
Total for 1934, 41·53.

Jan. 0·80. Fair.
Feb. 5·30. Very wet week ending 23rd. Also from 24th to 28th.
Mar. 0·56. Fair.
Apr. 4·63. Wet and cold.
May 2·49. Rain fell at the beginning and end of the month.
June 2·79. Fair and warm.
July 0·38. Dry. Drought conditions.
Aug. 4·71. No rain fell until 13th.
Sept. 8·16. Very wet through the month.
Oct. 6·34. „ „
Nov. 10·27. „ „

January to the end of November show an increase of 6·76 in. over the average of 12 months for the past 10 years, and 11 in. over 12 months for the past 5 years.

1934 nests

No. on map	Species	Site of nest	Eggs	Hatched	Flew	Remarks
1	Thrush (*a*)	Evergreen tree	4	0	0	Deserted early May
2	(*a*)	Hedge	4	4	4	
3	(*b*)	Laurustinus	4	4	4	
4	(*c*)	Evergreen tree	4	4	4	
5	(*d*)	Hedge	4	4	4	
6	(*e*)	Hedge	4	4	4	



For explanation of map see p. 315.

1934 nests (*cont.*)

No. on map	Species	Site of nest	Eggs	Hatched	Flew	Remarks
7	Blackbird	Hedge	4	4	4	
8	Swallow	Porch, June	5	5	5	
9		Boot shed, August	4	4	4	
10	Linnet	Yew hedge	5	4	4	One addled
11	Robin	Garage stoke hole	5	4	4	One addled
12	Hedge sparrow	Hedge	5	4	0	A cuckoo was hatched
13	Chaffinch	Pink hawthorn	5	5	5	
14	Goldfinch	Bird cherry	5	5	5	Early July
15		Apple tree, August	4	4	?	Cat destroyed nest after a week, found one young being fed by parent on grass the next day, after that no trace
16	Blue tit	Nesting box	3	0	0	One egg stolen, bird deserted
17	Great tit	Food hopper in verandah	8	0	0	Deserted, reason unknown
18	Starling (*a*)	Hole in ash	?	?	?	Saw young
19	(*b*)	Hole in ash	?	?	?	Saw young
20	Wren	In bank	?	?	?	Saw it building. Result unknown
21	Willow warbler, long grass	Nests located but did not look too closely for fear of making them desert				
22	Common whitethroat					
23	Lark					

Nests outside area:

24 Turtledove, south boundary
25 Partridge, garden, north boundary, 13 eggs, sucked
26 Flycatcher, north-west boundary
27 Nightingale, hedge, south boundary

1935 nests

No. on map	Species	Site of nest	Eggs	Hatched	Flew	Ringed	Remarks
1	Blackbird (*a*)	Hedge, early March	4	0	0	0	Deserted
2	(*a*)	Hedge, April	4	3	3	3	
3	(*b*)	Hedge, April	2	1	0	0	Chick dead. Cat ?
4	(*b*)	Hedge, late April	2	0	0	0	Sucked when two laid
5	(*c*)	Hedge, April	4	0	0	0	Sucked, nearly hatched
6	(*c*)	Hedge, May	4	4	4	0	
7	(*d*)	Hedge, late March	4	0	0	0	Deserted
8	(*d*)	Site, hedge sparrow (*a*)	4	0	0	0	Deserted torrential rain
9	Song thrush (*a*)	Shrub (Judas tree), early March	4	0	0	0	Deserted

Where more than one pair of each species are known (*a*), (*b*), (*c*) refer to separate pairs: thus two nests of thrush (*a*) are for the same pair.

Explanation of map on p. 314.

Map showing the types of trees and sites of nests found in 1934 and 1935. (1934 nest numbers in italic.)

O = oak (*Quercus robur*); o = oak sapling; A = ash (*Fraxinus excelsior*); a = ash sapling; P = pine (*Pinus sylvestris*). Small trees: s = sycamore (*Acer Pseudo-platanus*); sp = spindle (*Evonymus europaeus*); m = maple (*Acer campestre*); c = chestnut (*Aesculus*); w = willow (*Salix*); H = hawthorn (*Crataegus Oxyacantha*); h = hazel (*Corylus Avellana*); hol = holly (*Ilex Aquifolium*); hb = hornbeam (*Carpinus betulus*). ——— Hedges. – – – – Wire fencing. ∞∞∞∞∞ Undergrowth, consisting of bramble, holly and wild rose. The hatched area was not observed in detail.

1935 nests (*cont.*)

No. on map	Species	Site of nest	Eggs	Hatched	Flew	Ringed	Remarks
10	Song thrush (*a*)	Shrub (Sinicio-New Zealand daisy), April	4	4	4	4	
11	(*b*)	Hedge, April	4	0	0	0	Eggs disappeared
12	(*b*)	Hedge, early June	4	4	4	3	
13	(*c*)	Hedge, April	4	4	4	4	
14	Hedge sparrow (*a*)	Tiny cypress, March	5	5	0	0	Blown out. Gale
15	(*a*)	Yew hedge, April-May	4	2	2	2	Two addled
16	(*a*)	Yew hedge, late June	4	3	3	2	One addled
17	(*b*)	Thorn hedge, April	4	2	2	0	Two addled
18	(*b*)	Yew hedge, June-July	4	4	4	4	
19	(*c*)	Hedge, April	4	0	0	0	Eggs disappeared
20	Linnet (*a*)	Small box shrub, June, situated 1 ft. from kitchen window	4	4	4	1	
21	(*a*)	Apple tree, August	4	4	4	4	
22	(*b*)	Hedge, July	4	4	4	0	
23	Blue tit (*a*)	Nesting box, garden	9	3	3	3	Six eggs taken. Human
24	(*b*)	Nesting box, field	9	7	7	7	Two eggs addled
25	(*c*)	Under garage tile	?	?	?	0	Saw food being taken under tile to young
26	Great tit	Food hopper, verandah	7	7	5	0	2 died in nest
27	Swallow (*a*)	Porch, May	5	5	5	1	
28	(*a*)	Porch, July	4	4	0	0	All fell out. Shallow nest
29	(*b*)	Boot shed, May	4	0	0	0	Eggs disappeared
30	(*b*)	Boot shed, July	4	2	2	2	Two eggs disappeared
31	Goldfinch	Pink hawthorn in garden, May	5	0	0	0	Eggs disappeared Not human interference
32	Nuthatch	Oak tree, May	?	3	3	0	Three immatures fed here
33	Jay	Pine tree, May	0	0	0	0	Left nest after building

A pair of bullfinches began to build, but left after 2 days. Nest unmarked.
Located, but nest and contents not actually seen:

34 Robin; 35 Yellowhammer; 36 Wren. All in undergrowth.
37 Chaffinch. First nest deserted before eggs laid, could not locate the second.
38 Nightingale. Hedge of adjoining field to south.
39 Robin. West side of hedge field *C*, in bank of another garden. Heard young being fed.

The disasters to early nests were due to (1) gales and very cold weather in late March, following a spell of warm weather, (2) eggs disappearing: twice this was due to humans, but the rest unknown causes, (3) eggs sucked.

For the first time for many years, no cuckoo was reared.

As some birds had been ringed during the winter, the watching of the different couples was simplified.

Some nesting dates

Species	Begin nest	1st egg	Sitting	Hatch	Flew
Hedge sparrow (*a*), 1935	16 Mar.	24 Mar.	30 Mar.	8 Apr. (1) 9 Apr. (4)	Blown out 10 Apr.
(*a*), 1935	13 Apr.	20 Apr.	24 Apr.	4 May	15 May, 4 to 6 p.m.
Linnet (*a*), 1934	30 Apr.	11 May	15 May	29 May	11 June, 8 a.m. to 12 p.m.
(*a*), 1935	20 May	28 May	1 June	14 June	28 June
Thrush (*a*), 1935	Mar.	21 Mar.	25 Mar.	8 Apr.	28 Apr.
Swallow (*b*), 1935	28 June	6 July	23 July	11 Aug.	
Goldfinch, 1934	16 June	22 June	27 June 5 eggs	11 July	25 July, three at 8.39, one at 10.20. 26 July, last two. All returned to nest that night

Birds occurring on the area

Percentage of times each bird seen during the month	1934									1935										
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Counts per month ...	28	5	30	25	20	14	31	24	26	21	26	31	18	31	25	18	17	26	28	26
Crow (*Corvus corone*)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	6	4	—	4
Rook (*C. frugilegus*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Jackdaw (*C. monedula*)	61	60	63	20	30	14	29	25	46	43	46	22	6	6	20	17	—	4	43	27
Magpie (*Pica pica*)	3	20	10	20	30	14	3	25	—	10	—	11	7	1	9	3	1	2	4	19
Jay (*Garrulus glandarius*)	—	—	7	16	60	7	16	4	—	1	—	3	6	7	5	2	—	1	4	27
Starling (*Sturnus vulgaris*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Greenfinch (*Chloris chloris*)	50	80	37	76	20	—	—	—	—	10	11	6	6	42	32	100	35	4	—	50
Chaffinch (*Fringilla caelebs*)	100	100	100	100	100	100	100	100	100	76	100	100	100	100	100	100	100	54	100	100
Goldfinch (*Carduelis carduelis*)	3	80	100	100	100	35	39	—	—	—	4	3	22	100	72	100	23	8	7	—
Linnet (*C. cannabina*)	21	100	100	36	10	—	—	—	—	—	—	16	17	100	100	100	100	27	4	8
Bullfinch (*Pyrrhula pyrrhula*)	14	20	17	28	20	—	—	—	—	—	—	3	—	29	74	83	70	—	—	—
Yellowhammer (*Emberiza citrinella*)	18	20	60	44	10	7	6	—	—	—	8	22	78	100	100	100	41	11	4	—
House sparrow (*Passer domesticus*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Skylark (*Alauda arvensis*)	28	60	100	24	—	14	—	—	—	—	—	6	11	6	52	6	—	—	—	—
Pied wagtail (*Motacilla alba*)	7	20	33	4	5	50	32	8	—	—	—	9	28	3	4	—	29	50	4	8
Tree pipit (*Anthus trivialis*)	—	—	47	4	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—
Treecreeper (*Certhia familiaris*)	3	—	—	—	—	—	—	—	—	5	4	6	—	—	—	—	—	—	4	—
Wren (*Troglodytes troglodytes*)	46	20	47	32	65	35	22	20	15	23	31	74	61	26	8	—	18	4	25	50
Mistle thrush (*Turdus viscivorus*)	7	20	63	16	45	14	13	4	4	23	38	80	67	16	40	11	12	11	7	11
Song thrush (*T. philomelus*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Blackbird (*T. merula*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Redwing (*T. musicus*)	—	—	—	—	—	—	—	4	4	—	23	6	—	—	—	—	—	—	—	—
*Fieldfare (*T. pilaris*)	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—
Nightingale (*Luscinia megarhyncha*)	18	100	20	—	—	—	—	—	—	—	—	—	28	100	44	—	—	—	—	—
Redbreast (*Erithacus rubecula*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hedge sparrow (*Prunella modularis*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Spotted flycatcher (*Muscicapa striata*)	—	—	50	12	50	—	—	—	—	—	—	—	—	—	24	50	100	30	—	—
Chiffchaff (*Phylloscopus collybita*)	29	—	—	—	5	—	—	—	—	—	—	—	17	3	36	17	23	37	—	—
Willow warbler (*P. trochilus*)	14	100	63	100	30	21	—	—	—	—	—	—	22	39	16	100	100	—	—	—
Whitethroat (*Sylvia communis*)	7	100	66	48	55	—	—	—	—	—	—	—	6	66	100	28	53	—	—	—
†Gold-crested wren (*Regulus regulus*)	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	4	4
Long tailed tit (*Aegithalos caudatus*)	—	—	3	—	—	—	3	—	—	5	4	35	6	—	—	—	—	—	—	—
Great tit (*Parus major*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Coal tit (*P. ater*)	100	—	3	—	—	7	9	50	23	38	88	100	100	19	—	—	—	31	39	100

Birds occurring on the area (*cont.*)

Percentage of times each bird seen during the month	1934									1935									
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Counts per month ...	28	5	30	25	20	14	31	24	26	21	26	31	18	31	25	18	17	26	28	26
Marsh tit (*P. palustris*)	16	—	—	4	—	—	3	4	11	—	69	97	100	16	—	17	88	54	4	11
Blue tit (*P. caeruleus*)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Nuthatch (*Sitta europaea*)	64	100	26	40	50	29	22	25	11	29	11	48	66	35	100	100	65	46	14	42
Swallow (*Hirundo rustica*)	25	100	100	100	100	100	26	—	—	—	—	—	44	100	100	100	100	100	18	—
House martin (*Delichon urbica*)	—	20	47	32	35	21	29	—	—	—	—	—	—	—	16	6	29	61	32	—
Swift (*Apus apus*)	—	—	60	76	15	—	—	—	—	—	—	—	—	3	64	100	29	4	—	—
*Wryneck (*Jynx torquilla*)	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Green woodpecker (*Picus viridis*)	21	—	47	72	70	14	3	4	15	38	—	22	100	19	12	—	6	35	7	19
Greater spotted woodpecker (*Dryobates major*)	—	—	10	8	—	—	—	—	—	—	4	6	—	3	4	—	6	8	18	4
*Lesser spotted woodpecker (*D. minor*)	—	—	3	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cuckoo (*Cuculus canorus*)	53	100	100	16	—	—	—	—	—	—	—	—	33	31	100	—	6	—	—	—
Barn owl (*Tyto alba*)	14	—	—	4	5	—	—	—	—	—	—	—	9	—	—	—	—	—	—	—
Tawny owl (*Strix aluco*)	—	—	—	4	40	21	13	4	8	14	—	9	—	6	4	6	—	8	4	11
*Little owl (*Athene noctua*)	—	—	—	—	—	—	3	4	—	—	—	—	—	—	—	—	—	—	—	—
Kestrel (*Falco tinnunculus*)	—	—	—	4	—	—	9	—	—	—	8	—	6	6	—	—	6	—	4	—
Turtle dove (*Streptopelia turtur*)	—	—	100	100	5	—	—	—	—	—	—	—	—	42	72	100	—	—	—	—
Woodpigeon (*Columba palumbus*)	100	100	100	100	75	79	19	25	23	100	100	100	67	35	40	17	29	61	100	100
Common gull (*Larus canus*)	—	—	—	—	—	—	—	—	4	—	4	6	6	—	—	—	—	—	—	—
Lapwing (*Vanellus vanellus*)	25	—	26	4	—	—	3	—	—	—	—	48	6	9	—	—	—	—	—	—
Pheasant (*Phasianus colchicus*)	3	—	53	4	—	7	3	—	—	—	—	—	—	6	—	11	—	—	—	—
Partridge (*Perdix perdix*)	7	—	7	4	—	—	3	12	4	10	—	3	—	9	8	—	—	—	—	—
Swan (*Cygnus olor*)	—	—	—	—	—	—	3	—	—	—	3	—	—	—	—	—	—	—	—	—
†Mallard (*Anas platyrhyncha*)	—	—	—	—	—	—	—	—	—	8	16	—	—	4	—	—	—	—	—	3
Heron (*Ardea cinerea*)	—	—	—	4	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—

* Recorded 1934. Not seen 1935.

† Recorded 1935. Not seen 1934.

Notes. (1934). Mallard heard from pond near by, also moorhens (*Gallinula chloropus*).

(1935). Greenfinch: small flock came frequently to garden in November. Redwing: fed in fields near by, last half of November. Nightingale: heard, not seen; nest was on southern boundary. Spotted flycatcher: immatures fed on area in August. Marsh tit: immatures and parents fed on area in August. Moorhens heard daily on pond outside area. Mallard also often heard on same pond, but only counted if they flew over area. Woodpigeons: large numbers in October eating acorns.

A RECONNAISSANCE OF THE FAUNA OF AKPATOK ISLAND, UNGAVA BAY

By D. H. S. DAVIS

(*With Plate* 9)

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1. Introduction

The Oxford University Hudson Strait Expedition, under the leadership of H. M. Clutterbuck, spent about a month on Akpatok Island, Ungava Bay (in the Canadian Eastern Arctic), towards the end of the summer of 1931. An ecological survey was planned by the plant ecologist N. V. Polunin and the writer, who was assisted with the collecting work by A. K. Gregson, and by other members of the party. Observations on birds and mammals are especially due to Clutterbuck, H. P. Hanham, R. J. O. Bray and Ian H. Cox. I would like to thank the expedition members for their help in the survey; Charles Elton for valuable advice on technique and equipment before the expedition, and for help in many ways afterwards; Sir Edward Poulton, F.R.S., for his great kindness in distributing the collections for identification; and a number of specialists without whose co-operation the results of the survey could not be published: Dr A. R. Jackson (Araneida); Mr J. M. Brown (Collembola); Dr S. Finnegan (Acarina); Dr F. W. Edwards (Diptera-Nematocera); Mr J. E.

Collin (Diptera-Cyclorrhapha); Dr A. Roman (Parasitic Hymenoptera); Dr K. G. Blair (Coleoptera); Dr F. Laing and Mr R. Glendenning (Aphidae); Mr N. D. Riley and Mr W. H. T. Tams (Lepidoptera); Mr C. D. Soar (Hydracarina); Mr W. E. China (Hemiptera); Prof. W. M. Tattersall (Crustacea); and Mr G. C. Robson (Mollusca).[1]

The island lies some 80 miles west of Cape Chidley, in lat. 68° W., long. 60° 20′ N., and is about 28 miles long and 14 miles wide. Its geology and physiography have been fully described by Cox (1933) and a general account of the expedition with appendices on the scientific work is given in the *Geographical Journal* (Clutterbuck, 1932). The island consists entirely of horizontally bedded Ordovician limestone. The interior is an undulating plateau rising at one point to 930 ft. This plateau ends abruptly along the whole of the coast-line in perpendicular cliffs ranging from 100 ft. to over 600 ft. It is drained by watercourses, which start inland in shallow wide valleys. Towards the coast the valley sides steepen, until about a mile from the sea there is a sudden drop, the streams running at the bottom of steep-sided gorges or ravines. At this time (August) the streams were dry in the upper reaches.

The climatic conditions are severe owing to the position of the island in the storm-swept bay and the exposed nature of the plateau. During the expedition's stay the weather was exceptionally good. The mean day temperature was 48° F., with a slight drop at night. The plateau and more exposed valley slopes are swept bare of snow and the island is ice-bound during the winter.

In consequence of the adverse conditions and the universal limestone, the vegetation is uniformly poor. It has been described by Polunin (1934, 1935). There are no trees or shrubs, and except in certain sheltered areas (for example, near bogs, where sedges, cotton-grasses and grasses reach a height of about a foot) the plants grow close to the ground, mostly in scattered patches, and are never more than a few inches high. The most characteristic vegetation is an open community of *Dryas integrifolia* with associated *Salix*, *Saxifraga* mosses and lichens (see Polunin 1934, 1935).

It was not possible in the short time available to make more than a reconnaissance of the animal communities. Further, it was nearly the end of the summer: birds had finished nesting and were on the point of leaving; the flowering plants were over and many of the insects, particularly certain flies, had perished or gone into hibernation. Selected habitats within about 5 miles of the base camp in the south-east were worked, and the collections were supplemented from a few localities further afield. The survey is based mainly on collections made by A. K. Gregson and me between August 20 and September 18 1931. For the first fortnight in September Gregson made collections further inland, while I was ill. Three more days were put in after recovery.

[1] Collections of insects and spiders are in the Hope Department at Oxford; of mites and Mollusca in the British Museum of Natural History.

Phot. 1. The plateau of Akpatok Island: base camp tents in valley bottom.

Phot. 2. Limestone cliffs and intertidal rock-ledge: looking south from a point five miles north of the base camp.

DAVIS—AKPATOK ISLAND

2. Communities of the plateau

The desolate plateau of frost-shattered limestone is covered in most places with stone polygons. It is relieved only by scattered tarns and a few boggy depressions where vegetation is richer. The tarns, however, are shallow and often barren of higher plant life; but they are the breeding grounds of Chironomid flies, whose larvae are sought by wading birds.

(*a*) *Bare stone-polygon fjaeldmark*

What little vegetation there is grows round the edges of the polygons and consists chiefly of *Dryas integrifolia*, *Salix arctica*, mosses and lichens. It forms a typical high arctic fjaeldmark (stony desert) with an open plant community. The animals found in this type of country are as follows:

Mammals[1]

Polar bear	*Thalarctos maritimus*
Arctic fox	*Alopex lagopus*

Birds[1]

Rock ptarmigan	*Lagopus rupestris*
Lapland bunting (=Lapland longspur)	*Calcareus lapponicus*
Snow bunting	*Plectrophenax nivalis*
Horned lark	*Otocoris alpestris*
American golden plover	*Pluvialis dominicus*
Snowy owl	*Nyctea nyctea*

Araneida (Spiders)

Lycosa fuscula Thor.
L. disjuncta Jackson
Tarentula insolita L. Koch
Hilaira leviceps L. Koch
Cornicularia karpinskii Camb.
Meioneta nigripes Sim.

Acarina (Mites)

Bdella littoralis L.
B. vulgaris var. *decipiens* Thor
Rhagidia gelider Thor.
Bryobia praetiosa C. L. Koch
Oribatidae (indet.)

Lepidoptera

Geometrid moth	*Entephria polata brullei* Lef.
"Woolly bear" Arctiid moth larva	*Apantesis quenselii* Hübn.

Parasitic Hymenoptera

Ichneumonid	*Ichneumon* sp.
Braconid	*Apanteles* sp. near *alticola* Ashm.
,,	*Apanteles* sp. near *nitens* Mues.
,,	*Macrocentrus* sp.

[1] Names of mammals and birds follow Anderson & Taverner in their articles in "Canada's Eastern Arctic" (Ottawa, 1934), except that the mammal subspecies are not used, there being no skins available.

HEMIPTERA

Aphid	*Microsiphum* sp.

DIPTERA

Mosquito	*Aëdes* sp.
Dung fly (Cordylurid)	*Scatophaga lanata* Lundbk.

COLLEMBOLA (SPRINGTAILS)

Entombrya erratica Brown
Achorutes muscorum Templ.
Isotoma olivacea var. *canadensis* Brown
I. viridis (Bourl.)
Pseudisotoma sensibilis (Tullb.)

MOLLUSCA

Snail	*Vertigo modesta* (Say)

OLIGOCHAETA (WORMS)

Enchytraeidae (indet.)

In a bird's nest on the plateau (probably belonging to a Lapland bunting) the following mites were found: *Cyta latirostris* var. *brevirostris* Thor; Oribatidae (indet.); and large numbers of Parasitidae (indet.).

The normally carnivorous polar bears, which were seen a number of times on different parts of the island, sometimes with cubs, subsist on the scanty vegetation when the seals that they normally hunt on the ice are not available. Plants were found grubbed up, and the contents of the gut of the one specimen that was shot consisted entirely of vegetable matter. Holes or trenches were found dug under the brow of a slope for shelter. Another animal marooned by the breaking up of the winter sea-ice was the arctic fox. Only occasional traces, dung and footprints, were found. Foxes must rely for food on birds, their eggs and young (e.g. ptarmigan).

Rock ptarmigan were seen in all parts and nothing but the shoots of plants was found in their crops. Leaves of *Salix*, *Saxifraga*, *Politrichum viviparum*, and *Oxyria digyna* commonly occurred in them. The Lapland bunting was commoner than the snow bunting, and was confined more to the valley heads and the plateau near them. Its presence was no doubt due to the abundant fly fauna to be found in such sheltered places near boggy ground.

The only habitats available for most vertebrates on the open plateau were beneath stones and at the roots of plants. Small animals were very sparsely distributed. The larvae of *Apantesis quenselii* were frequently seen, and were feeding on anything they could get. The aphids, *Macrosiphum* sp., were found in an immature apterous stage in the seed capsules of *Dryas integrifolia*. They were only found once (by H. P. Hanham), and in spite of intensive search were not discovered again. No beetles or butterflies occurred and only a few stray flies.

(*b*) *Grassy depression*

In a small sheltered dip clothed with grasses, cotton-grass and sedges the following animals were found, showing how a little extra shelter enables certain delicate flies to survive.

DIPTERA: *Boletina arctica* Holmgr. var. (a Mycetophilid)
Steringomyia popoffana Towns. (a Calliphorid)
PARASITIC HYMENOPTERA: *Plectiscus* sp. (an Ichneumonid)
Apanteles sp. near *alticola* Ashm. (a Braconid)
APHIDAE: *Anuraphis* or *Rhopalosiphum* sp.
ARANEAE: *Erigone arctophylacis* Crosby & Bishop

These were collected from the vegetation in the hollow with a sweep net.

(*c*) *Swallow-hole*

The drainage of the plateau depends mainly on streams but in places swallow-holes occur which take off the snow water. At one of these, an early snow run-off, a luxuriant growth of *Taraxacum* sp. and *Oxyria digyna* had developed and covered a small depression about 10 ft. across. Settled here were vast numbers of *Scatophaga futilis* Malloch (eighty were caught in one sweep of a net) and a few *Fucellia ariciiformis* Holmgr. and *Acroptena* sp.

(*d*) *Erratic boulders*

These boulders represent the only igneous material on the island, and their weathering enables the ptarmigan to fill its gizzard with quartz. But for their presence it is doubtful whether any of these birds could live on the island, as limestone is unsuitable. Around the boulders there was always evidence of the activity of the birds, and their droppings may influence the vegetation to some extent. In such places a thick mat of *Cassiope* and *Empetrum* had developed. In the moss on the boulder were found:

COLLEMBOLA (SPRINGTAILS): *Entomobrya erratica* Brown
PARASITIC HYMENOPTERA: *Apanteles* sp. near *alticola* Ashm. (a Braconid)
ARANEAE (SPIDERS): *Coryphaeolanus holmgreni* Thor
ACARINA (MITES): Oribatidae (indet.)

3. COMMUNITIES OF THE VALLEYS

Animal life, particularly invertebrate, is much richer in the shelter of the valleys where it benefits also by the thicker vegetation covering the less steep and stabler slopes. In winter only the open, more poorly vegetated slopes are swept clear of snow. The vegetation resembles that of the plateau, though with a somewhat greater variety of plants. The fauna also is much the same, only with a greater number of individuals; while certain animals such as butterflies, flies and beetles owe their presence to the less severe conditions obtaining in the summer.

(*a*) *Valley head with bog pools*

In this region, where the vegetation forms a "hillock tundra" with small pools interspersed, the most characteristic animals are the large numbers of Chironomid flies whose larvae are found in numbers in the pools. The following animals were found at the margin of pools:

BIRDS

Lapland bunting (=Lapland longspur)	*Calcarius lapponicus*

ARANEIDA (SPIDERS)

Lycosa fuscula Thor.
L. disjuncta Jackson
Hilaira whymperi Jackson
Erigone arctophylacis Crosby & Bishop
Coryphaeolanus holmgreni Thor

ACARINA (MITES)

Penthaleus haematopus Can.
Cyta latirostris var. *brevirostris* L. Koch
Eupodes variegatus Koch
Oribatidae (indet.)

LEPIDOPTERA

Fritillary butterfly	*Brenthis chariclea obscurata* McLach.
Clouded yellow butterfly	*Colias hecla hecla* Lefebr. (=*groenlandica* Lampa)

PARASITIC HYMENOPTERA

Ichneumonid	*Aclastus* sp.
,,	*Plectiscus* sp.
Braconid	*Apanteles* sp. near *alticola* Ashm.

COLEOPTERA

Staphylinid beetle	*Atheta* sp.

DIPTERA

Mycetophilid fly	*Coelosia truncata* Lundst.
,,	*Boletina arctica* Holmgr. var
,,	*B. akpatokensis* Edwards
Chironomid gnat	*Cricotopus basalis* Staeg.
,,	*Metriocnemus ursinus* Holmgr. (?)
,,	*Spaniotoma* (*Psectrocladius*) *obvius* Walk.
,,	*S.* (*Orthocladius*) *frigidus* Zett.
,,	*S.* (*Orthocladius*) *oblidens* Walk.
,,	*Spaniotoma* sp.
Empid fly	*Hydrodromia aucta* Zett
Dolichopodid fly	*Hydrophorus glaber* Wlk.
Anthomyid fly	*Limnophora* (*Spilogona*) sp.
,,	*Acroptena* sp.
,,	*Paregle radicatum* L.
,,	*Fucellia ariciiformis* Holmgr.
Dung fly (Cordylurid)	*Scatophaga futilis* Malloch

COLLEMBOLA (SPRINGTAILS)

Entomobrya erratica Brown
Isotoma olivacea var. *canadensis* Brown
Folsomia quadrioculata (Tullb.)
Achorutes muscorum Templ.

OLIGOCHAETA (WORMS)

Enchytraeidae (indet.)

The buntings were flocking at this period, but it appeared that the Lapland buntings' territories were at the valley heads and extended to the plateau near. The snow buntings, which were less common, seemed more confined to the plateau. Their feeding grounds were in the neighbourhood of boggy areas where there was an abundance of flies. The predatory Empid fly *Hydromia aucta*, although not caught with prey, was commonly found. The mites,

spiders, Collembola and small earthworms were living amongst or under stones and at the roots of plants at the bog margin. Skating on the surface of the pools was the Dolichopodid fly *Hydrophorus glaberwek*. The following animals were found in the pools:

Coleoptera: *Agabus semipunctatus* Kby.
Hydroporus glabriusculus Aub.
H. tartaricus Lec.
Diptera: Chironomid larvae

(*b*) *Better vegetated slopes*

These slopes, although rocky, form an almost closed "hillock tundra" plant community and in small areas a heath-mat is developed. The tussocky vegetation consists chiefly of *Dryas integrifolia*, *Cassiope tetragona*, *Salix* spp., *Saxifraga*, spp., *Polygonum viviparum*, *Vaccinium uliginosum* var. *microphyllum*, *Carex* spp., and a number of mosses and lichens. The animals found in such areas are:

Birds

Rock ptarmigan	*Lagopus rupestris*

Araneida (Spiders)

Lycosa fuscula Thor.
L. disjuncta Jackson
**Dictyna borealis* Camb.
Erigone arctophylacis Crosby & Bishop
E. tirolensis L. Koch
Scotinotylus ungavensis Jackson
Cornicularia karpinskii Camb.
Typhochrestus borealis Jackson
Hilaira frigida Thor.
H. leviceps L. Koch
Oreonetides vaginatus Thor.
Leptyphantes audax Sörensen
L. complicatus Jackson

Acarina (Mites)

Bdella capillata var. *pallipes* L. Koch
B. vulgaris var. *decipiens* Thor
B. littoralis L.
Cyta latirostris var. *brevirostris* L. Koch
Rhagidia gelider Thor.
Trombidium sucidum L. Koch
Podothrombium strandi Berlese
Oribatidae (indet.)

Lepidoptera

Fritillary butterfly	*Brenthis chariclea obscurata* McLach.
Clouded yellow butterfly	*Colias hecla hecla* Lefebr. (=*groenlandica* Lampa)
Geometrid moth	*Entephria polata brullei* Lef.
Noctuid moth	*Sympistis zetterstedtii* Stgr.

Parasitic Hymenoptera

Ichneumonid	*Ichneumon* sp.
,,	*Cratocryptus* sp.
,,	*Delomerista* sp.
,,	*Mesochorus nigriceps* Ths.

* Recorded as *Dictyna major* Menge by Dr Jackson (1933); later (1934) he found it to be *D. borealis*.

COLEOPTERA

Weevil	*Lepyrus labradorensis* Blair

DIPTERA

Chironomid gnat	*Diamesa gregsoni* Edwards
"	*Spaniotoma* (*Orthocladius*) *oblidens* Walk.
"	*Spaniotoma* sp.
Hover fly	*Platychirus* sp.
Carrion fly (Calliphorid)	*Steringomyia popoffana* Towns.
Anthomyid fly	*Paregle radicatum* L.
Dung fly (Cordylurid)	*Scatophaga furcata* Say (*squalida* Mg.)
Helomyzid fly	*Scoliocentra thoracica* Collin
Ephydrid fly	*Scatella stagnalis* Fln.

COLLEMBOLA (SPRINGTAILS)

Entomobrya erratica Brown
Achorutes muscorum Templ.

MOLLUSCA

Slug	*Arion* ? *hortensis* Fér.
Snail	*Vertigo modesta* (Say)

The under surface of stones was the chief habitat for the majority of insects, spiders and mites. Collembola were extremely abundant and evidently formed the major source of food for the great variety of spiders. The little snail, *Vertigo modesta* lived in small colonies in drier parts, while the slug *Arion* (?) *hortensis* was found in moister conditions. The fritillary had a quicker and more erratic flight than the clouded yellow and kept more to the lower parts of the drier slopes; whereas the clouded yellow seemed to haunt the more sheltered terraces on the higher ground. Neither was seen after the end of August. The moth *Sympistis zetterstedtii* was very commonly seen darting about from the shelter of one tuft of vegetation or stone to another. On dull cold days it hid beneath stones. In wet places Chironomid larvae were found living among the moss, otherwise they were mostly found sheltering under stones and occasionally flying.

(*c*) *Poorer slopes*

The vegetation resembles that of the plateau and is of the open "fjaeld-mark" type with scattered patches of plants. The surface is dry and rocky. The fauna is intermediate between that of the plateau and that of the better vegetated slopes. The slopes at the mouths of the ravines are less well vegetated. The following were found:

BIRDS

American pipit	*Anthus spinoletta*

ARANEIDA (SPIDERS)

Lycosa fuscula Thor.
L. disjuncta Jackson
Erigone arctophylacis Crosby & Bishop
E. arctica White
Coryphaeolanus holmgreni Thor.
Hilaira frigida Thor.
H. leviceps L. Koch
H. whymperi Jackson
Meioneta nigripes Sim.

Acarina (Mites)

Bdella vulgaris var. *decipiens* Thor.
B. littoralis L.
Cyta latirostris var. *brevirostris* L. Koch
Rhagidia gelider Thor.
Trombidium sucidum L. Koch
Penthaleus haematopus Can.
Bryobia praetiosa C. L. Koch
Parasitus sp.
Oribatidae (indet.)

Lepidoptera

Fritillary butterfly	*Brenthis chariclea obscurata* McLach. (=*groenlandica* Lampa)
Arctiid moth	*Apantesis quenselii* Hübn.
Noctuid moth	*Sympistis zetterstedtii* Stgr.

Parasitic Hymenoptera

Ichneumonid	*Ichneumon* sp.
,,	*Platylabus* sp.
,,	*Microcryptus* sp.
,,	*Mesoleius lituratus* var. *sahlbergi* Woldst.
Braconid	*Apanteles* sp. near *alticola* Ashm.

Coleoptera

Carabid beetle	*Cryobius mandibularis* Kby.
,,	*Curtonotus brunneipennis* Dej.
Staphylinid beetle	*Boreaphilus nearcticus* Blair

Diptera

Mosquito	*Aëdes* sp.
Biting fly	*Simulium vittatum* Zett.
,,	*Simulium* sp.
Hover fly	*Syrphus* (*Epistrophe*) sp.
,,	*Platychirus* sp.
Empid fly	*Hydromia aucta* Zett.
Tachinid fly	*Tenuirostra arctica* Sack.
Carrion fly (Calliphorid)	*Steringomyia popoffana* Towns.
Anthomyid fly	*Acroptena* sp.
,,	*Paregle radicatum* L.
,,	*Fucellia ariciiformis* Holmgr.
Dung fly (Cordylurid)	*Scatophaga islandica* Beck
Ephydrid fly	*Scatella stagnalis* Fln.

Collembola (Springtails)

Entomobrya erratica Brown
Achorutes muscorum Templ.
Schötella ununguiculata (Tullb.)
Sminthurinus niger (Lubb.)

Mollusca

Snail	*Vertigo modesta* (Say)

The blood-sucking *Simulium* ("Black fly") and the mosquito *Aëdes* were very scarce, and no one was bothered by them. It is probable that they were much more numerous earlier in the season when they would have been a pest. The American pipit's territory extended from the lower parts of the ravine to the drift line. Its food consisted of flies, particularly the abundant scavenging flies *Scatophaga islandica* and *Fucellia ariciiformis* and Chironomids. *Entomobrya erratica* was again the most abundant springtail, being found in great numbers under stones. *Sminthurinus niger*, another springtail, occurred

under stones in damp places near watercourses. One dead specimen of the Arctiid moth *Apantesis quenselii* was found, but no live ones were seen. A parasitized pupa of this species was found under a stone. The numerous caterpillars, found mainly on the plateau, presumably pupate before winter and emerge in the following summer.

It is worth noting that no Chironomid flies were caught on these slopes. Near the main watercourse, that runs at the bottom of a perpendicular cliff on one side they were found in some numbers flying near or settled on stones in the stream. These were all small delicate species whose larvae were abundant in the stream at this point, attached to the filamentous Algae. Those found were *Diamese davisi* Edwards, *D. gregsoni* Edwards, *D. bohemani* Goet., *D. clavata* Edwards, and *D. furcata* Edwards. These and probably others, were seen in small swarms hovering over the base of a slope towards dusk.

4. Fresh-water communities

The fresh-water system consists of scattered isolated tarns on the plateau, with streams running from the watershed to the sea. In August and September, the upper reaches are dry. The fresh-water fauna was not collected at all completely. Tarns may be surrounded with vegetation or not. In either case the fauna appeared to be similar. Chironomid larvae, Oligochaete worms, Copepods, Ostracods and a fairy shrimp (Phyllopod) were seen. The water mite *Lebertia porosa* Sig Thor, and water beetles *Agabus semipunctatus*, Kby., *Hydroporus glabriusculus* Aub. and *H. tartaricus* Lec. hunted amongst the detritus at the bottom. The long-tailed duck or old squaw (*Clangula hyemalis*) was seen in the vicinity of the tarns and the white-rumped sandpiper (*Pisobia fuscicollis*) was observed feeding on red Chironomid larvae in the mud at the edge. There are no fish in the tarns or streams; and the latter appear barren except for a large number of Chironomid larvae attached to Algae on stones in the slower moving reaches near the sea.

5. Shore-line communities

(*a*) *Recent shingle*

Between the bottom of the slopes and the shingle that gets covered by the sea lies a strip of slightly worn shingle which has a small fauna similar to the slopes. The springtail *Entomobrya erratica* Brown, the spiders *Coryphaeolanus holmgreni* Thor. and *Erigone arctophylacis* Crosby & Bishop and the Staphylinid beetle *Olophrum boreale* Payk. lived under and amongst the stones. The following mites were found amongst the stones: *Eupodes variegatus* Koch, *Cyta latirostris* var. *brevirostris* L. Koch, *Bryobia praetiosa* C. L. Koch, *Bdella vulgaris* var. *decipiens* Thor, *Rhagidia gelider* Thor. and Oribatidae (indet.). The first-named was the most abundant. The carrion fly *Cynomyia cadaverina* Desv. was attracted to the bear carcase which lay on the shingle and

another species of *Cynomyia* (indet.) came round the tent. In a sheltered dip at the edge of the shingle, among a thick clump of *Ammodenia peploides*, a small colony of plant-sucking animals were congregated. Of the Aphids (Hemiptera-Homoptera), there were large numbers of immature *Pemphigus* sp. (cf. *lactucae*), a few winged adults of *Thelaxes* sp. (cf. *dryophila*) and one unidentifiable specimen of another species. There were also several Psocids (indet.) and one Anthocorid (Hemiptera-Heteroptera) nymph. It is possible that the Anthocorid preyed on the Aphids. Mr Glendenning in his report says: "A species of *Pemphigus* comparing well with *lactucae* Fitch. This specimen is a fall migrant, and these sexuparae of *Pemphigus* offer no known characters co-relating them with the better known spring migrants, which latter is the usual one described. *Lactucae* Fitch is suspected to be the sexuparae of *populicaulis* Fitch or *brevicornis* Hart, which two species are not well separated, and may be synonymous."

It is not unlikely that the *Pemphigus* sp. represent the fall migrants of Aphids upon poplars (*Populus tremuloides*) on the south of Ungava Bay, where the tree limit nearly reaches the coast.

(*b*) *Drift line*

The decaying seaweed and other jetsam at high tide mark is the breeding ground of the flies *Scatophaga islandica* Beck and *Fucellia ariciiformis* Holmgr. These flies occur in countless numbers flying over the drift line and shingle stretches. Small Oligochaete worms swarmed in the seaweed. The spider *Erigone tirolensis* L. Koch was also found. The American pipit (*Anthus spinoletta*) was feeding on the flies. There was usually one pair of these birds at the mouth of a ravine. White-rumped sandpipers (*Pisobia fuscicollis*) visited the drift-line and appeared to be eating the springtails *Hypogastrura viatica* (Tullb.), *Archisotoma besselsi* (Pack.) and *Isotoma olivacea* var. *canadensis* Brown which were quite plentiful. They also ate dead shrimps and other material. *Bdella littoralis* L. was very plentiful on the shingle right up to the edge of the sea. Large numbers were seen in the drift-line debris. One was discovered eating the small Chironomid fly *Diamesa clavata* Edwards, which had been sheltering in a crevice on the cliff side. *Bdella littoralis*, although primarily a shore animal, was found right inland on the plateau, a circumstance noted also in North-East Land, Svalbard (Summerhayes & Elton, 1928, p. 262).

(*c*) *Intertidal ledges*

At the base of the perpendicular cliffs, ledges run out to sea. These are covered at high tide and are subject to terrific ice action in winter. In the crevices and small pools left by the retreating tide were shrimps (*Gammarus locusta*) and snails (*Littorina rudis*). Both occurred in considerable numbers and probably served as food for the migrating birds.

6. Cliff communities

(*a*) *Guillemot "rookeries"*

At two points on the island, in the north and south-west, the cliffs are exceptionally high. At both of these places very extensive colonies of guillemots were living. (These are thought to have given the name to the island, Eskimo *Aukpat'tók* "The island of guillemots".) They seem to affect the vegetation near the edge of the cliff, where a mat of *Saxifraga oppositifolia* has developed, owing to the manuring of the edge by birds' droppings. Brünnich's guillemot (*Uria l. lomvia*) nested in thousands on the cliff face and glaucous gulls (*Larus hyperboreus*) nested near and preyed on them. Mandt's guillemots (*Uria grylle mandti*) which feed in small flocks at sea, usually near the shore, probably nested close by. After the first week in September the rookeries became more and more deserted as the birds migrated south.

(*b*) *Cliff line*

At intervals along the coast pairs of peregrine falcons (*Falco peregrinus*) with young were nesting on the upper parts of the cliffs. There was a nest to each ravine and several near the bird cliffs. Glaucous gulls were seen chasing them. When the bear carcase was lying on the hillside a raven (*Corvus corax*) passed overhead, and appeared again on several successive days.

7. Discussion

The exposed position of the island together with its meagre plant covering are the main factors responsible for the simple structure of the animal communities. The island, although not within the geographical arctic, lies well north of the tree-limit. The vegetation is infinitely poorer than the mainland round Ungava Bay and of Southern Baffin Island. Nevertheless the number of species of invertebrates found (on a small portion of the island at the end of the summer) was considerable, amounting to over a hundred. There are probably many more living on the island at the height of summer; this great variety is doubtless due to the position of the island in a Bay that is surrounded by regions where a much richer fauna must exist. But little is known of this fauna and it is impossible to say whether the new species that were found are common also on the mainland. The commonest springtail *Entomobrya erratica* was new, and a new variety of *Isotoma olivacea canadensis* came also (Brown, 1932). Of the spiders, a large proportion were common to Britain (Jackson, 1933) the rest being either circumpolar forms or new species.

The food relations that bind these animal communities together are evidently fairly simple, but can only be indicated broadly owing to lack of detailed observations on the habits of the animals. Animals dependent on plant material, living or dead or dying, were the polar bear, ptarmigan,

butterflies and moths and their larvae, a weevil, a slug and snail, Chironomid, scavenging shore- and other flies, Aphids, some mites, springtails and earthworms.

The fox, snowy owl, peregrine falcon and glaucous gull depend on birds for food, since there are no mice or lemmings on the island itself. The pipit, buntings, sandpiper, lark and golden plover seem to be insectivorous. No vegetable matter was found in the stomachs of the pipits and buntings examined, and there were no identifiable animals. The long-tailed duck feeds on the aquatic animals in the tarns and pools. Of the carnivorous invertebrates the spiders form the chief part, feeding on springtails, mites and flies. Empid flies prey on other flies; and some mites, notably the Bdellids, are carnivorous or more probably omnivorous. Mosquitoes and Simuliid flies possibly rely to some extent upon plant juices in the absence of blood (see Longstaff, 1932, p. 129). The few ground beetles are predaceous and the water beetles hunt Crustacea and other animals in the pools. Ichneumonids, Braconids and Tachinid flies parasitize the larvae of other insects. Finally there are the carrion feeders: the raven and a few flies.

The fauna is richer than Svalbard or Bear Island (Summerhayes & Elton, 1923, 1928) and East Greenland (Madsen, 1936) but poorer than West Greenland (Longstaff, 1932) or the continental parts of Arctic Canada (Johansen, 1921); but the ecological structure of the animal community is similar, with its arrangement of spiders, mites, springtails, Chironomid and shore flies, insectivorous and plant feeding birds, and their enemies the owls and falcon.

8. Summary

A description is given of a barren island where conditions for animal life are severer than the nearby mainland. The fauna is of a high arctic type, but includes a greater variety of species than would be expected, owing to its proximity to the mainland, whence the fauna is derived. The animal interrelations are less complicated than in West Greenland but more so than in Spitsbergen. The simplicity is due to the geographical position, the geological formation and poor vegetation of the island.

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AN INVESTIGATION INTO THE RELATION BETWEEN CHAFER LARVAE AND THE PHYSICAL FACTORS OF THEIR SOIL HABITAT

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(*With* 3 *Figures in the Text*)

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1. Introduction

Up to the present time most of the ecological work carried out on soil insects has been confined to surveys of the existing faunas; little attempt seems to have been made, on the other hand, to define the conditions in this important habitat except from the botanical point of view (**6**, **9**, **15**). Cameron (**3**) and Sweetman (**16**) have, however, contributed preliminary descriptions of the subject, and Waksman (**14**) has written a comprehensive treatise on the technique of soil microbiology. There seems to be little interrelation between the different species in this habitat, so that a clear knowledge of the physical factors would appear to be of the utmost importance.

The investigations described here were undertaken to discover some relation between factors making up the microclimate of the soil and the behaviour of the larvae of chafer beetles which inhabit it. The oval, larval and pupal stages of these insects, comprising 98 % of their total life history, are all spent in this environment. Only exceptionally do they come to the surface while immature, and then only for a very short time. Even in the imaginal stage long spells may be passed in the soil, e.g. overwintering *Melolontha*, which may spend several months below ground before emerging.

In all experiments, except where otherwise stated, the material used was second-year larvae of the brown chafer (*Serica brunnea* L.), most of which were obtained by the kind help of Mr J. M. B. Brown, of the Forestry Commission.

For measuring the relative humidity of microclimates, a special apparatus had to be designed. In principle this consisted of a very small sensitive portion, constructed of a single pine-cone bract, which could be introduced into the microhabitat; the movements of this bract were then measured electrically at any convenient distance. The apparatus was accurate to 1% in a steady humidity, but was unfortunately very slow in recording alterations; this, however, was not of great importance in this study, since rapid changes in moisture were seldom encountered. Soil moistures were determined in the usual manner, namely, by weighing and drying at 103° C. small samples of the wet soil. This gives results correct to about 0·1%.

2. Soil factors

Chafer larvae differ from most other insects inhabiting the soil, in that they form a hollow cell in the soil around them. I have found that the larvae, except when placed in the soil while in a quiescent state (which of course would not be a natural phenomenon), immediately form this cell by pressing the soil outwards with their legs and body. If the larva is unable to build this cell for any reason, such as the ground being baked too hard or the hole becoming filled with water, it succumbs after a number of days, according to the temperature and rate of metabolism.

This cell, which is common to all the British Melolonthinae, is somewhat ovoid in shape and varies in size with the larva. That of a full-grown *Melolontha* larva is usually about 3–4 cm. at its longest diameter and 2·5 cm. at its shortest. The cell of *Serica* is of course much smaller and is usually not more than 1·2 cm. at its longest diameter.

This space contains a special microclimate which is controlled partly by the conditions of the surrounding soil and partly by the external climate of the locality. In studying any given climate there are a number of meteorological factors which have to be considered and which may or may not affect it. As far as surface conditions are concerned these have been fully discussed by Uvarov (**13**) and de Gryse (**5**). Notes on the main factors in soil are given below.

(*a*) *Light*

It is obvious that since the particles of most soils are opaque to light, this factor can have no direct effect on the climate below the surface. In summer, however, solar radiation has more influence on raising the temperature of the soil than any conduction from the air. When light strikes the soil it is converted into heat, so this factor is best considered with the other forms of heat affecting the soil. These larvae are of course negatively photographic.

(*b*) *Atmospheric pressure*

Very little seems to be known of any direct effect of pressure on insects, and all experiments have indicated that they can survive very low pressures for some time. To check this conclusion, I subjected five larvae of *Serica* to a pressure reduced to 8 in. of mercury. The temperature was kept at 10° C. so that the rate of metabolism and oxygen requirements should be low. Even after 14 days the larvae were still living and apparently healthy. It would thus seem that the small variations in barometric pressure found in nature can have little effect on the larvae. Pressure does of course have a small influence on the relative humidity and the rate of evaporation of water.

(*c*) *Wind*

It is obvious that the air in soil cannot be directly affected by wind, except very near the surface. This purely aerial climatic factor can, however, be replaced in soil by that which controls the rate of diffusion of the varying atmospheres, which are described in the next section.

(*d*) *Composition of the air*

Variations in composition do not occur in aerial habitats, though they are of importance below the surface of the soil. Russell & Appleyard (**12**) state that there are in soil two zones of air which depend on the texture. The air found in the spaces between the particles near the surface is similar to atmospheric air. Below this the gases dissolve in the soil water and the air becomes deficient in oxygen.

I checked the reaction of *Serica* larvae to an atmosphere of this latter type, since it seemed likely they would encounter it at hibernation level. Larvae were placed in tubes of soil in which nearly all the oxygen had been replaced by carbon dioxide. The temperature was maintained at 5° C., and the larvae were found to survive for 5–8 days. It would thus seem that at winter temperatures the oxygen requirements are low enough for chafer larvae to survive in almost anaerobic conditions.

(*e*) *Soil temperature*

Mail (**7**) has carried out a preliminary study of winter temperatures in the soil and their relation to the survival of insects. He found that the surface soil is rapidly affected, but there is a time lag increasing with the depth of the soil. Thus the temperature below 45 cm. is not altered by changes in surface temperature lasting less than a day; and the lower depths show a very near agreement with the surface mean over a long period. He also noted that the temperature of the surface soil followed that of the air less closely when the soil was covered with a vegetation such as grass. Mail also showed that there is a main temperature inversion taking place in spring and autumn, when the deeper soil ceases to lose and gain heat respectively.

I have plotted temperature curves throughout the year, using apparatus similar to that described by Mail (**7**). These showed that except in winter there is a sharp drop in temperature during the daytime at about 20 cm. caused by the cooling at night and warming in the day. On the other hand, in all seasons except summer depths lower than this are warmer than the surface.

McColloch & Hayes (**8**) found that whenever there is distinct change in temperature gradient, as found by Mail in spring and autumn, chafer larvae move from the colder to the warmer regions.

It can be shown that the amount of moisture present plays an important part in altering the specific heat and therefore in the temperature of the soil. The specific heat of most soils in the dry state is about 0·2 (that for sample G in Table 1 below was 0·217), while that for water is of course 1·000. Thus the more water there is in the sample, the nearer will the specific heat of the damp soil approach to unity, and consequently more heat will be required at the surface to raise the temperature at lower levels.

The converse of this is of importance for the survival of these larvae in winter conditions, when there is usually a larger proportion of water in the soil: the quantity of heat per volume of soil is larger, so that the time taken for a fall of temperature is lengthened. If the temperature of the air falls during the night below the undercooling point of the insect, that of damp soil is less likely to reach this point than is dry soil: so that the insect has more chance of survival.

I have found that the larvae of *Serica* do not become really dormant during winter. While metabolism is reduced to a minimum, probably owing to low temperature and excessive moisture, the larvae are not incapable of movement even when kept at a temperature as low as 4° C. Larvae kept in these conditions were normally quiescent, but moved freely if stimulated by being shaken. If the larvae in the soil during winter are stimulated by adverse conditions they are capable of movement to the optimum level even if the temperature is only a few degrees above their fatal zone. This is true of course only when there is sufficient depth of soil, e.g. in certain Dorset pastures inhabited by chafers, only 5 in. of soil overlies the solid chalk.

(*f*) *Soil moisture*

The water content of an insect's environment influences it in many ways, but much less has been written on this subject than about temperature. The variations in moisture content to which soil insects are subjected are much larger than those found in aerial environments, since, except for precipitation, air insects meet with relative humidities varying only from 1 to 100%. Soil habitats, on the other hand, may also have moisture contents increasing up to complete saturation of the soil with water.

Cameron (**3**) points out that the water in soil may be divided into three main types: *gravitational*, *capillary* and *hygroscopic*. The points at which each

of these reaches its maximum are known as the *saturation*, *critical* and *hygroscopic* points respectively. According to recent research (**6**) these distinctions are quite arbitrary, but are, however, very useful in practice; the *saturation point* is defined as that at which all pore spaces are filled with water, a space which of course varies with the state of the soil; the *critical point* is the one at which no more water can be extracted from the soil by centrifuging at 1000 times gravity (**1**); while the *hygroscopic point* is defined as the amount of water present in air-dry soil at 20° C.

Although centrifuging only gives an arbitrary critical point, plant physiologists have found that there is a direct relation between this point and the soil water content at which plants begin to wilt (**4**).

I determined the saturation and critical points for a number of soils in which *Serica brunnea* was known to occur and also for a few inhabited by the allied species *Melolontha melolontha* and *Amphimallus solstitialis*. These results are shown in Table 1. The critical point is expressed as the percentage

Table 1. *Water constants of soils inhabited by chafers*

Soil sample	Saturation point per 100 parts dry soil	Critical point	
		Per 100 parts dry soil	% of saturation
Sand	24·3	3·89	16·1
Clay	146·7	63·2	43·0
A (*Serica*)	84·8	32·8	38·6
B „	82·1	38·2	46·6
D „	75·7	31·7	41·8
E „	85·4	28·1	32·9
G „	68·7	25·9	37·7
F (*Melolontha*)	115·5	49·2	42·5
H „	82·2	23·6	28·8
C (*Amphimallus*)	91·7	37·3	40·7

of saturation, as well as in the more usual form of the weight per 100 parts of dry soil, as the former was found to express better the soil moisture contents. Determinations by the same technique for sand and clay, as samples of the coarsest and finest soils, are also included for the sake of comparison.

The table shows that the saturation point may vary from 24·3 to 146·7 parts, while those soils inhabited by *Serica* only cover a range of from 68·7 to 85·4 parts. In the case of the critical point the total range is from 3·8 to 63·2, while the habitat of *Serica* varies from 25·9 to 38·2 parts. Sample F was selected as representing one of the heaviest soils occupied by *Melolontha melolontha* and shows that this larva is able to survive in a much heavier and damper soil than the other two species.

Recent research (**6**) indicates that above the critical point the relative humidity of the atmosphere in soil can be considered as practically saturated. Below this point, however, there is a gradual fall which becomes more and more rapid as the soil water decreases. In air-dry soil the relative humidity in the soil is of course equal to that of the surrounding atmosphere.

Curves were plotted showing the water content at different depths in soils inhabited by these larvae. In wet weather the surface content is high, but below this the water rapidly drains off to lower levels. Thus at the level at which these larvae usually live, the water content rarely rises much above the critical point. In dry weather on the other hand, the top centimetre becomes practically air dry; below this the rise in content is rapid, but unless rain has fallen recently, the water content does not attain the critical point until a level well below that ever reached by these larvae.

Owing to this, in localities occupied by chafers, the water content will not fall below the hygroscopic point at a level greater than about 4 cm., even after a considerable drought; also generally speaking there will be an increase in water content of the soil as the depth becomes greater. These insects are therefore practically always surrounded by an atmosphere which is saturated with moisture; a circumstance which is of considerable importance when considering the way in which their habitat differs from that of aerial insects.

3. Influence of soil factors on the larvae

In the foregoing sections some account has been given of the physical factors in the soil. It now remains to be shown what influence these have on the survival, behaviour and life history of the chafer larvae which inhabit these soil layers.

Laboratory experiments were carried out on larvae of *Serica*, in which they were submitted to known conditions of temperature and humidity in order to discover their reactions.

(*a*) *Influence of moisture*

Water content of larvae. Investigations were undertaken to discover what influence, if any, the water content of the soil, stated as a percentage of saturation, had on the concentration of the larval body fluids. Batches of five *Serica* larvae, all of the same stage, were placed in test-tubes containing soil with a known water content and at 15° C. The larvae remained in these conditions at a constant temperature for a period varying from 6 to 14 days; though they usually came into equilibrium after about 5, the longer period was used as a control.

The total and bound water contents of the larvae were found according to the method described by Robinson (**10**). This relies on the fact that at −20° C. all the free water and none of that bound by the colloids, is frozen. Thus if the weighed larva is allowed to thaw in a small quantity of water in a calorimeter, the heat taken up owing to the latent heat of fusion of ice indicates the amount of free water present, being calculated from the formula

$$X=\frac{FN(T_3-T_4)-SW(T_2+T_4)}{80-\left(\frac{T_2-T_1}{2}\right)},$$

where N is the volume of water in the calorimeter;
T_3 is the temperature of the water at start;
T_4 is the temperature of the water at finish;
S is the specific heat of the material;
T_2 is the temperature of the material before mixing;
T_1 is the average freezing point of similar material;
W is the weight of the material;
F is the correction factor for the calorimeter.

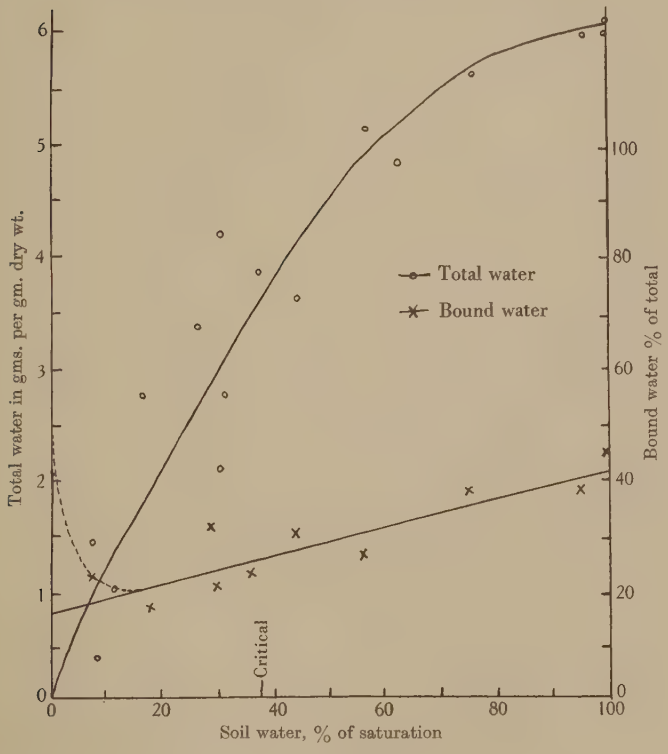

Fig. 1. Water content of larvae at 15° C.

The total weight of water is found by drying the larvae at 100° C. and reweighing. The bound water is then the difference between the weights of the free and total water. The results of these experiments are seen in the graph, Fig. 1 below, and also in Table 2.

It will be noticed that the total water is expressed as g. per g. dry weight of larva. This was found to give a more accurate indication of the state of the insect in these experiments, since the total weight of the larva alters

Table 2. *Results of water content and freezing-point experiments*

Soil water % of salt	Total water g. per g. dry wt.	Bound water % of total	Freezing-point °C.	Undercooling point °C.
100	6·04	45·6	−0·2	−1·7
	6·08		−0·9	−2·0
94·7	6·00	38·2	−0·3	−1·0
			−0·9	
75·4	5·65	38·0	−0·7	−1·4
			−1·0	−2·0
62·3	4·85	—	—	—
56·1	5·15	26·7	−0·9	
			−1·1	−2·0
44·0	3·62	30·6	−0·7	−1·5
36·8	3·89	23·0	−1·2	—
31·2	2·75	—	—	—
30·1	2·10	21·2	−0·9	−2·1
	4·27	32·2		
26·6	3·40	—	−1·1	—
17·4	2·25	18·6	−1·4	−2·5
				2·9
12·4	1·00	—	−2·3	−4·0
7·5	1·47	24·0	—	—
	0·41			

considerably as water is taken up or lost. Therefore the usual method of expressing the water as a percentage of the total weight of larva is confusing.

Fig. 1 illustrates that there is a distinct relation between the total water in the body fluid of the larva and the water content of the soil it is inhabiting. At low humidities, i.e. below the concentration represented by the hygroscopic coefficient, the loss in water sustained by the larva is very rapid and apparently uncontrolled, owing no doubt to the fact that the air surrounding it is not so nearly saturated with water, so causing evaporation from the larva. Beyond this point and below the critical point, the relation is almost direct and the curve consequently a straight line.

Above the critical concentration the gain in body fluid with an increase of soil water becomes less rapid. It will be realized that over this range the larva comes into contact with a greater amount of free water, so that the balance of osmotic pressures plays an increasingly important part. A point is reached at which the larva is in saturated soil and completely surrounded with water, when the osmotic pressure of the body fluid and the soil water will tend to become balanced, as shown by the curve.

In the same figure the curve for the bound-water content, expressed as a percentage of the total water, is also shown. It illustrates that all the points lie approximately on a straight line sloping upwards as the water content of the soil increases. The fact that this curve appears to originate from a point near 18% of the total water, is only hypothetical, since it is impossible to obtain accurate readings with this technique when there is little or no free water present.

Although Robinson (**10**) has shown that a minimum of bound water always remains after the material has been dried at 100° C., it appears more likely that the curve for bound water would rise sharply to 100% of total water at zero soil water, when it reaches the point where the total water begins to fall off rapidly; this is shown in Fig. 1 by the dotted line. It also follows from the method used in estimating the total water that the curve for this quantity should pass through the origin.

In dealing with bound water, it may be mentioned that Robinson (**10**) has also shown that the lowering of temperature has little effect on the bound water content of chafer larvae, a phenomenon so often found in the case of winter-hardy insects. Even when this worker kept the temperatures of these larvae only just above their freezing-point for a considerable period of time, there was only a very slight rise in the quantity of bound water in relation to the total. This was also found by Sweetman (**16**).

These studies of the relation between the larvae and the water content of the soil provide an explanation of why the larvae are found only in certain soils.

The soils with a fairly low saturation point, inhabited by chafers, are incapable of holding large quantities of water and so increasing the body fluid of the larvae and consequently causing retarded metabolism or death. Also the comparative lowness of the critical point—about 30 parts per 100 of dry soil as compared with 63·2 parts for clay—shows that the average surface of the particles is not large. This keeps fairly low the point below which surface tension plays the leading part in the water relation and the loss in body fluid becomes large.

There is also a biotic factor in the ecology of chafers which is affected by moisture, namely the development of parasitic Fungi. The optimum point for these seems to lie between soil water contents of 60 and 80% of saturation; in no case, in the writer's experience, did parasitic Fungi develop when the larvae were completely immersed in water.

Survival at low humidities. Experiments were then undertaken to determine what was the lowest atmospheric humidity at which *Serica* larvae could survive. Larvae were placed in small uncorked tubes containing a little air dry soil. These were then placed in larger tubes partly filled with solutions of caustic potash calculated to vary the humidity of the air as described by Buxton & Mellanby (**2**). The air humidity in each tube was then checked with the hygrometer mentioned earlier in this paper.

It was ascertained that as long as the larvae were prevented from burrowing in the soil and forming a cell, not one was able to survive for long in any humidity below saturation.

This fact led the writer to believe that in forming a cell, which consists of hard packed soil relatively impermeable to air, the larvae were able to isolate a small atmosphere. If the humidity of this atmosphere should fall below

saturation, small quantities of water, evaporating from the body of the larva, would raise this humidity to saturation again and so prevent further dangerous loss of body fluid.

This theory was tested by surrounding with soil which had dried in air at 56% humidity, the sensitive portion of the hygrometer in a small sealed vessel. When the whole had come into equilibrium, the indicated moisture was noted and part of the soil near the hygrometer replaced by a number of large *Serica* larvae; the vessel was again sealed and the temperature kept constant. The larvae immediately started to form a rough cell by pressing out the soil around them, and the readings on the hygrometer indicated that the air was becoming more moist until it reached 68% when the larvae died.

The soil in this experiment was of course considerably drier than that which the larvae would be able to tolerate normally, but the results indicate clearly that if the fall in relative humidity is only slightly below saturation, the larvae are able to survive provided they can reduce the diffusion of the air by forming a cell.

Migration in relation to soil moisture. The fact that the larvae of chafers appear to move up and down in the soil with changes in the amount of water in the medium around them, has been previously mentioned in this study.

In experiments, these larvae were usually placed in tubes of soil containing a known water content; I noticed that in tubes of low water content, i.e. below about 30%, the larvae were nearly always found at the base of the tube, even after so short a time as 30 min. In tubes above 80% of saturation, on the other hand, the larvae remained on the surface where they had been placed and never attempted to burrow down. At concentrations between these two points the positions of the larvae varied.

To determine the range of soil water contents usually occupied by the larvae of *Serica*, a 2·5 cm. glass tube 70 cm. long was filled with soil of a water content varying from saturation at the lower end, to air dry soil at the upper; a number of larvae were then placed at regular intervals throughout the tube. After 8 days the contents of the tube were removed and the water in the soil surrounding each larva was determined by drying and weighing. It was discovered that the soil round the larvae had water contents lying between 31·3 and 55·8% of saturation, except for one instance of a desiccated larva in soil with a water content of 9·7%.

The range occupied is therefore particularly small. Comparison with Fig. 1 shows that it fits fairly accurately the straight line relation between soil water content and body fluid concentration. It may thus be correct to assume that the above range represents the optimum soil water content for the larvae of this species and stage of development.

(*b*) *Influence of temperature*

Freezing and undercooling points. Further experiments were carried out to discover the variations, if any, in the freezing and undercooling points of larvae which had been kept in soil of different water contents. The technique employed was that described by Robinson (**11**) using a contact thermocouple in connexion with a suitable galvanometer and potentiometer. Robinson has shown that the usual method of measuring the internal temperature of insects with a piercing thermojunction is faulty, since the physical injury so caused often raises both the freezing and undercooling points by some degrees. He described a means for correlating the external temperature as indicated by a contact thermocouple, with that of a piercing junction.

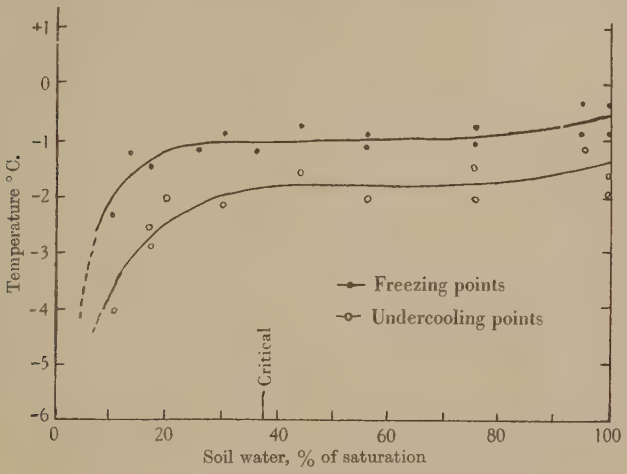

Fig. 2. Freezing and undercooling points of larvae.

For larvae to freeze the temperature must first be lowered to the undercooling point; when this is reached a sudden jump in temperature occurs to the true freezing point, when the formation of ice begins. In no case in my experience did any larva of this species survive this process, even if the temperature was not again lowered to the undercooling point, as is frequently necessary with other insects.

This technique was therefore adopted using a single larvae of *Serica* and the results are shown in the accompanying graph, Fig. 2. Between 25 and 75 % of saturation the freezing point is practically constant at nearly $-1{\cdot}0°$ C.; when the soil water is below this range, there is a very rapid drop in freezing point. This may be compared with the curve showing the water content of the larvae in Fig. 1, in which there is rapid fall in body fluid below 25 % soil water and thus this fall in freezing point would be expected.

The curve for the undercooling point which is also given in Fig. 2, illustrates that there is a fairly constant difference between these temperatures and the corresponding freezing points. There is however a tendency for the undercooling point to approach the freezing point as low soil water contents are reached. It is of course impossible to determine either of these points when they are very near each other, since this technique relies on the appreciation of the rise of temperature from the undercooling point to the freezing point.

It will be observed from Fig. 2 that there is a slight rise in both the freezing and undercooling points between 75% and saturation. This would appear to be deleterious to the larvae, since in winter conditions are usually damper and the larvae are in more danger from freezing than in summer. It is to be recollected however that frosts usually occur in fine, clear weather; it is probable therefore that in the light and well-drained soils occupied by these larvae, any previous rain will have drained off to below this relatively high water content of 75% of saturation.

Survival at high temperatures. A further set of experiments was carried out to determine what relation there was between the highest temperature at which these larvae could live and the water content of the soil they were inhabiting. Batches of five larvae were placed in tubes containing soil of known water content as described above, and after an interval of a few days in which to allow the larvae to come into equilibrium with their surroundings, the tubes were immersed in a water bath of known temperature for 15 min. On removing the larvae it was found to be impossible to ascertain the living specimens from those which had died, owing to the fact that they were suffering from heat coma. When in this condition the larvae were perfectly normal in appearance, but did not respond to any stimulus and thus indicate that they were alive. After an interval of 4 days, however, those living had returned to normality, while those which had not survived the treatment, took on the characteristic brownness of death. The living specimens were then subjected to a temperature one degree higher than in the previous test and so on until all larvae were dead; the temperature at which they died being noted. The relation between the mean temperatures and the soil water content in which each particular batch was situated is shown in Fig. 3.

It will be realized of course that below about 10% of saturation points on this curve cannot be obtained, since under these conditions the low humidity prevents the larvae from surviving at any temperature as described above. From this point up to 60% the relation is practically direct, the temperature increasing steadily for each increment in soil water. Above 60% up to saturation the temperature of survival falls rapidly and the relation is only approximate as indicated by the fact that the points lie rather wide of the curve.

The observation that there is an optimum temperature just above 60% and a fall as the soil water decreases from this, might be explained by the

larvae having a greater tendency to suffer from water loss at these high temperatures, possibly owing to an increase in respiration. Mortality would therefore be due to water loss rather than to the direct effect of high temperature and this portion of the curve is thus comparable to the similar range in Fig. 1. The extremely rapid fall in the survival temperature above 60% is probably caused by the insect coming into contact with greater quantities of free water, as explained in a previous section, and thus being less well insulated from the

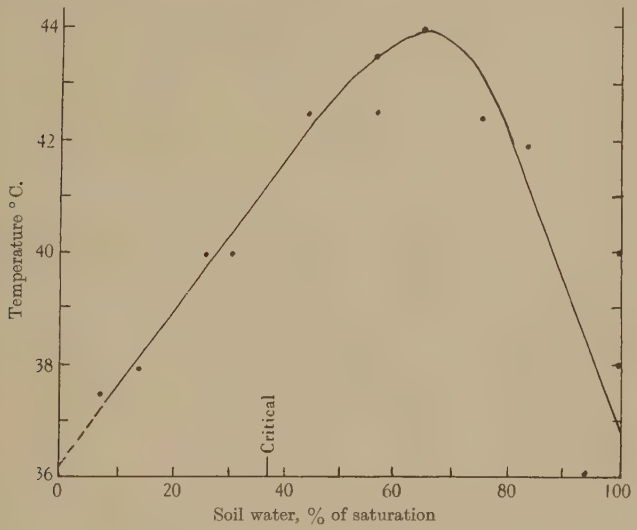

Fig. 3. Thermal death points of larvae.

external temperature. Since the atmosphere is saturated in all cases on this curve, it is unlikely that evaporation should play any large part in the balance of survival, as would occur with animals inhabiting the open air.

4. Discussion

From the foregoing survey of the different factors encountered by the larvae of *Serica*, some general conclusions may be drawn. It is for instance fairly apparent that the mean of the factors controlling the habitat chosen by chafers, represents roughly the optimum conditions for the life of these insects. These are however continually varying about the mean and thus at different times each may in turn become the limiting factor.

In *winter* it appears that the temperature near the surface of the soil may reach a point below that which the insect can tolerate. The larva is however able to evade this by migration down into the soil; but here it encounters

other limiting factors, such as the lack of oxygen and food, both of which are inclined to retard metabolism.

In *autumn* the limiting factor seems to be the excess of soil moisture in the presence of relative high temperatures; this condition is in itself inclined to be fatal, but it also induces the development of fungoid and bacterial diseases.

In *summer* conditions may vary in an exactly opposite way to this, in that the larva may suffer from the lack of moisture. Drought also has the indirect effect of killing the vegetation and thus removing the food supply of the larva at a time when high temperatures have induced rapid metabolism and a particular need for nourishment. It appears unlikely that in areas occupied by this species of chafer, the temperature of the soil will reach a point high enough to be in itself fatal to the larva.

5. Summary

1. It is pointed out that since the larvae of chafers live in cells in the soil, they are enclosed in a microclimate of which the main factors are discussed. The most important of these are proved to be soil heat and soil moisture.

2. The chief characteristics of soil heat are summarized and it is shown that there is a marked time lag behind the air temperatures, the climate in the soil therefore being less extreme than that above the surface.

3. Soil moisture is considered to consist of three main types, namely hygroscopic, capillary and gravitational, the latter two being the most important to the larvae.

4. Experiments are described in which a relation is demonstrated between the water content of the soil and the concentration of the body fluid of the larva. It appears that larvae are unable to survive in an air humidity lower than saturation unless they can form a cell in which air movement is limited; the larvae are able to raise the humidity a small amount per cent by evaporation without dangerous loss of body fluid.

5. A relation between the freezing points of the larvae and the water content of their habitat is also demonstrated. It is observed that there is little change in the freezing point over the range of moisture usually occupied by the larvae. Above and below this range conditions may be fatal.

6. The survival of these larvae in relation to high temperature and soil water content was also investigated. These experiments prove that there is a steady rise in tolerated temperature as the soil water increases towards 60% of saturation; above this point there is however a rapid fall.

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A MODIFIED GREENWICH NIGHT-CLOUD RECORDER USED FOR ECOLOGICAL WORK

By C. B. WILLIAMS

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(*With Plate* 10 *and* 2 *Figures in the Text*)

In the course of some work in the Entomological Department at Rothamsted on the nocturnal activity of insects, it became necessary to have a measure of the cloudiness of the sky during the night. After considerable search and enquiry it was found that an instrument for providing this information existed at the Royal Observatory, Greenwich, and had been briefly described in the *Greenwich Meteorological Observations*, 1931 (Introduction, pp. 8-9).

The principle of the machine consists in producing an image of the pole star on a photographic plate by a lens of about 18 in. focal length. As the pole star is not quite at the centre of apparent rotation of the heavens, the image so produced makes a circle on the plate of about two-thirds of an inch in diameter. The camera is opened after dark and shut before dawn to prevent fogging. If the night is clear there is an unbroken arc of the image of the star on the photographic plate; if it is cloudy there is no image; and if it is partly cloudy the image forms a broken arc. The instrument at Greenwich is a large wood box camera, using a glass "quarter-plate" each night. It is placed out of doors and the shutter of the lens is opened and closed each night at specified times by a watchman.

At Rothamsted there was no night watchman, so the opening and closing of the shutter had to be made automatic. We also made other structural alterations including the use of a small roll film camera to contain the records for 16 successive nights and an arrangement that permitted the instrument to be indoors, taking the photograph through the lower part of a sash window facing to the north. The following is a description of the modified instrument which has now been in continual use for over 2 years and has proved quite satisfactory.

In the instrument as finally constructed (see Plate 10) we used the body of a small Zeiss Ikon Box Camera (*A*) taking two photographs on each of the 8 divisions ($1\frac{3}{8} \times 2\frac{1}{2}$ in.) of a V.P.K. film (Kodak film, No. 127). The camera body was extended by means of a brass tube (*B*) to a length of 18 in. and at the end a shutter (*C*) with an 18-in. focal length spectacle lens was fitted. Beyond the shutter is an extension shading tube (*D*) fitting loosely into a guard tube (*E*) which passes through a block of wood in the window frame, represented by the scale (see also Fig. 1). The lens is stopped down to an aperture of $\frac{1}{2}$ in. (F/36). The shutter is actuated by a weight (*F*) which can be wound up each day and is controlled by an escapement (*G*). The structure of the escapement

will depend on the exact nature of the movement required for working the shutter. In the present case every alternate half rotation allowed by the escapement either opens or closes the shutter. The timing is worked by the mechanism of an alarm clock (*H*)[1] reduced by Meccano gears to a 24-hour rotation on a timing disc (*I*). On the front of this disc are two movable struts (*K*) with pegs at the end of each which actuate the escapement. The

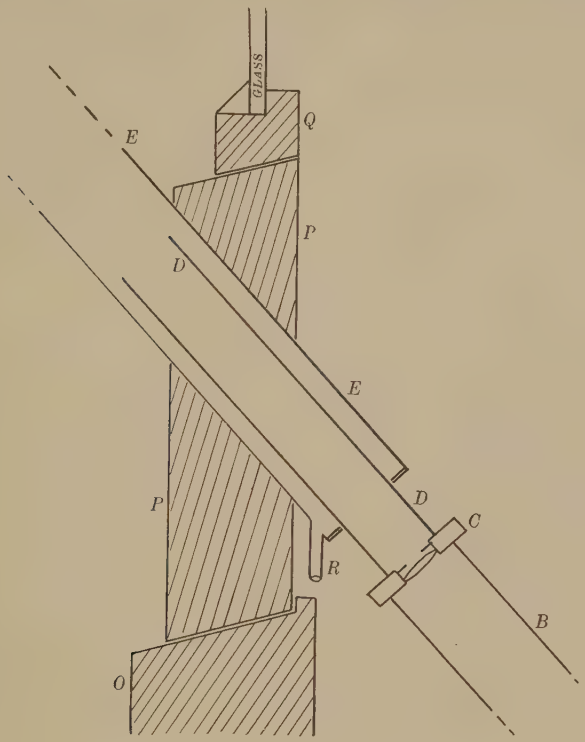


Fig. 1.

struts are tightened up by a central thumb screw. One of the pegs strikes the escapement in the late evening and allows the weight to open the shutter; and the second strikes the escapement before dawn and allows the shutter to be closed.

As the timing disc is marked with the 24 hours the pegs can be set to open and shut the shutter at any required time. A pointer (*L*) indicates the current time on the disc. The whole apparatus is fitted on a base board (*M*) which is in turn screwed to the side wall of the window.

[1] An electric synchromotor would probably be more satisfactory.

As it is not possible to see the image of the pole star on the focussing screen of the camera, two peep sights (N_1 and N_2) have been fitted. They are adjusted beforehand so that when the sun (or similar strong source of light) is in a line with them, its image is on the middle of the film. These peep sights are then sighted on the pole star on a clear night before the baseboard is screwed down, and final adjustments are made by developing one or two test films and making the necessary alterations to the screws.

Fig. 1 shows diagrammatically the method adopted for fitting the instrument to a sash-window frame. The lettering of the camera is the same as above. O is the lower portion of the window frame. P is a wood block about 11 by 3 in., running across the whole of the bottom of the window, through which the guard tube passes as nearly as possible at the correct angle. Q is the lower window which now comes to rest on the top of the block. The way in which the inner shading tube projects into the guard tube is shown and also

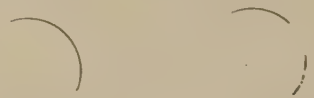


Fig. 2.

the small side tube R on the guard tube which allows the escape of any rain that may get in. The instrument is fixed on the extreme right of the window so that the mounting board can be screwed to that side of the window opening.

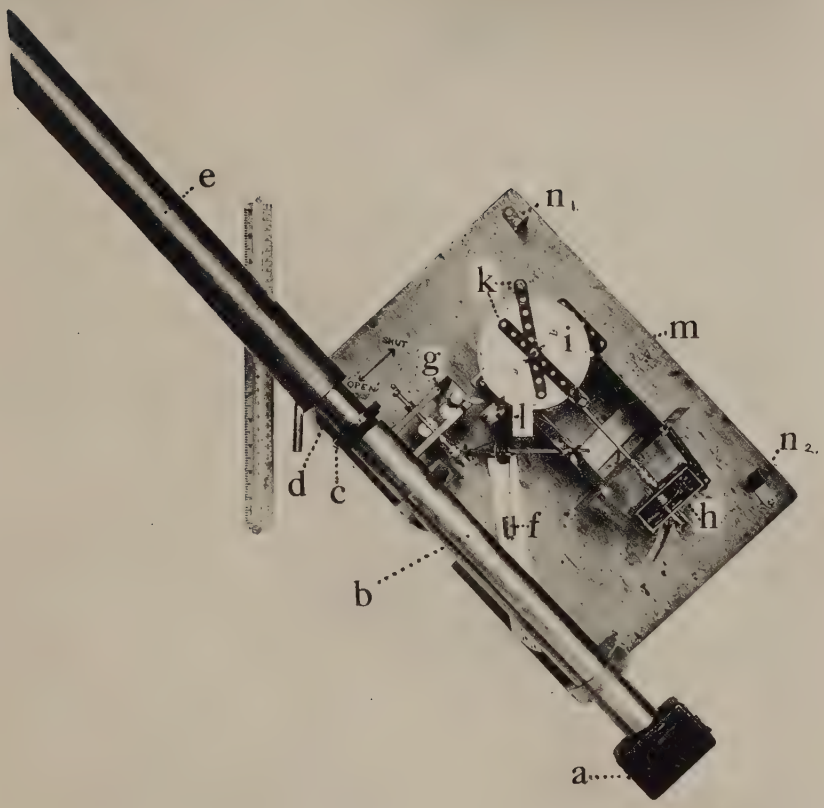
The timing of the shutter is changed every 10 days according to a table kindly supplied by Mr W. M. Witchell of Greenwich. The times are about 1 hr. 15 min. after sunset (or before sunrise) in mid-winter; falling to about 1 hr. 5 min. at the March equinox, then rising to about 1 hr. 35 min. at mid-summer and back to 1 hr. 5 min. at the September equinox.

Two typical results are shown full-size in Fig. 2. For detailed examination the film is superimposed on a photographically reduced scale, and examined with a low power microscope. It is possible to read to within a few minutes error the duration of clear and cloudy sky during the night.

General use of the results is of course based on the assumption that the sky in the neighbourhood of the pole star is a fair sample of the rest of the sky. This is reasonably correct in the latitude of London, but the instrument could not be used in the tropics where the pole star is only a few degrees above the horizon; nor, of course, is it in its present form of any value in the southern hemisphere.

Summary

A simple instrument is described for automatically recording on a photographic film the duration of cloudiness at night over the pole star, based on one originally designed at Greenwich Observatory.



The complete instrument: for explanation see text.

WILLIAMS—NIGHT CLOUD RECORDER

Face p. 350

THE ROOKERIES OF SOUTH MANCHESTER AND DISTRICT

By S. CRAMP and J. H. WARD

(*With 3 Figures in the Text*)

1. Introductory

The distribution of rookeries has received considerable attention from ornithologists of recent years, and it has been found that similar factors appear to determine this distribution in different parts of the country. The following census, undertaken in a rather different district from others previously studied, was intended to provide yet a further check on these factors.

2. Area and rookeries

The area consists of 96 sq. miles of mixed territory in the neighbourhood of south Manchester. A large portion in the north (see Fig. 2) is thickly populated, whilst further south there are a few smaller towns and villages, surrounded by arable land. With the exception of a ridge of hills in the extreme east, the land is very flat. There are two main river systems—the Mersey and the Bollin, with numerous tributaries, and a number of small isolated streams.

As found previously, no satisfactory definition of a rookery is possible without an intensive study of feeding areas, and this was unfortunately impossible in this case. In all, 1691 nests were found in the area, and for convenience these have been divided into forty-three rookeries. In the majority of cases it proved relatively easy to determine the limits of a particular rookery; but in case of doubt allocation was made after consideration of the particular circumstances of each group of nests. The rookeries were distributed in order of size as follows:

Table 1

Nests	Rookeries
0– 25	27
26– 50	7
51– 75	3
76–100	2
101–150	1
151–200	1
201–250	1
251–300	0
301–350	1

Average no. of nests per rookery = 39·3.

The majority of the rookeries were counted in April, and as found by Alexander (**1**), a considerable increase was noted in many cases between the end of March and mid-April. Owing to the growth of foliage it is not usually possible to make the count later than this.

3. Factors determining distribution

The Nicholsons (**2**), after their Oxford survey, suggested the following three main factors as having the greatest influence on distribution: altitude, the proximity of rivers and geological formation. Later Wynne (**4**), in the Isle of Wight, suggested that rooks appeared to favour the neighbourhood of buildings, especially of old houses in gardens and parks. The influence of each of these factors on the distribution of the rookeries in the South Manchester district will be considered in turn.

Altitude. The following table shows the distribution of rookeries and nests in relation to altitude:

Table 2

	Rookeries	Nests	Area (sq. mile)	Nests per sq. mile
Sea-level to 250 ft.	34	1166	62·1	18·7
250–500 ft.	8	478	27·8	17·1
Over 500 ft.	1	47	6·1	7·7

The difference in the density of nests on land under 250 ft. and land 250–500 ft. is only small, and may not be significant, but above 500 ft. the density is notably lower. Further the one rookery with 47 nests situated over 500 ft. was located on a narrow ridge, within easy reach of a river valley, about 150 ft. below, and here the birds were usually observed feeding below the 500 ft. level.

Proximity of rivers. The rooks in the area appeared to show a marked preference for nesting sites near to rivers or streams (see Figs. 1 and 3), and only one rookery was situated more than $\frac{3}{4}$ mile from running water. The rivers in the greater part of the area are adjoined by fertile meadows, and these being ideal feeding grounds are undoubtedly the main attraction. It is significant that no nests were found on the lower reach of the Bollin, where for 2 or 3 miles the river is bordered by steep banks, often wooded. Similarly, there was only the one rookery on the land over 500 ft. in the east, which, although traversed by two streams, does not provide the same rich meadows for feeding purposes.

Geological formation. Practically the whole of the area consists of New Red Sandstone, with the exception of Carboniferous measures in the eastern hills, and a thin strip of Permian formation near Hazel Grove and Stockport. In this area the rooks do not appear to show a preference for any particular geological formation.

Buildings. Several rookeries were located in the grounds of large houses, where as Roebuck (**3**) suggests, the good grassland provides suitable feeding grounds. In the towns few nests were found, owing to the lack of suitable trees for nesting purposes, and adequate food supplies within reasonable range. In themselves the noise and bustle of the towns do not appear to deter the rooks; thus at Longford Park, Stretford and Woodsmoor Lane, Stockport, flourishing rookeries were found practically adjoining busy main roads.

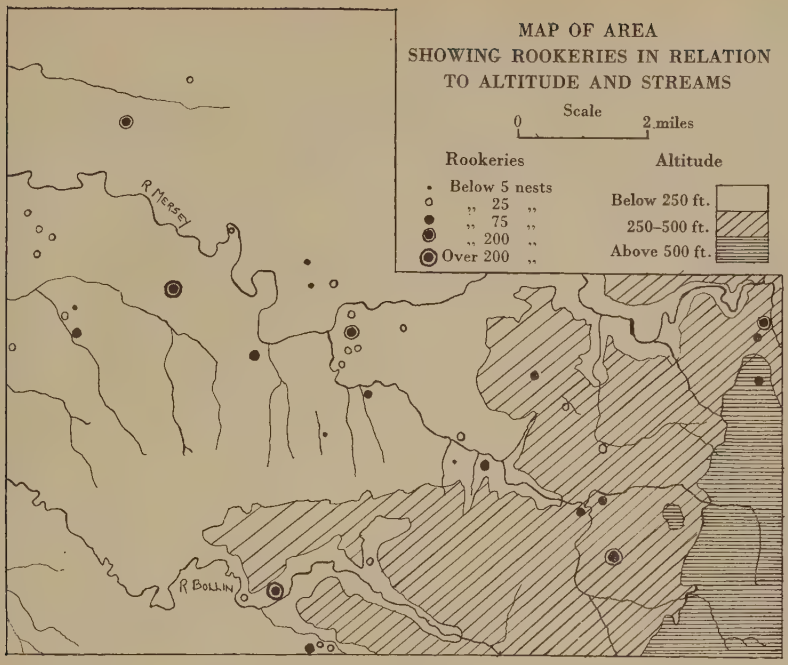

MAP OF AREA
SHOWING ROOKERIES IN RELATION
TO ALTITUDE AND STREAMS
Scale
0
2 miles
Rookeries
Below 5 nests
,, 25 ,,
,, 75 ,,
,, 200 ,,
Over 200 ,,
Altitude
Below 250 ft.
250–500 ft.
Above 500 ft.
R Mersey
R Bollin

Fig. 1.

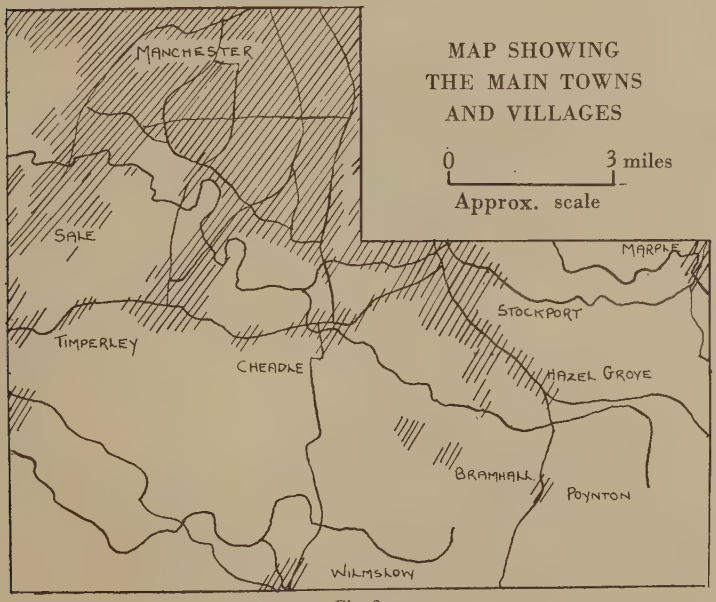

MAP SHOWING
THE MAIN TOWNS
AND VILLAGES
0
3 miles
Approx. scale
MANCHESTER
SALE
TIMPERLEY
CHEADLE
STOCKPORT
MARPLE
HAZEL GROVE
BRAMHALL
POYNTON
WILMSLOW

Fig. 2.

The rook's main requirements at nesting time are, first, suitable trees for nesting, and secondly, meadowland for feeding purposes. In the Manchester area trees are fairly plentiful in the open country and the latter is therefore the most important factor. Suitable meadows are usually found in the river valleys below 500 ft., and only in two instances were rookeries found either over 500 ft. or away from a river or stream. Having regard to this, Fig. 3 showing nests per sq. mile becomes readily comprehensible. The region is divided into squares, each containing 4 sq. miles, and seven of these were without nests. Of these *A* 3 in the north consists of a thickly populated part

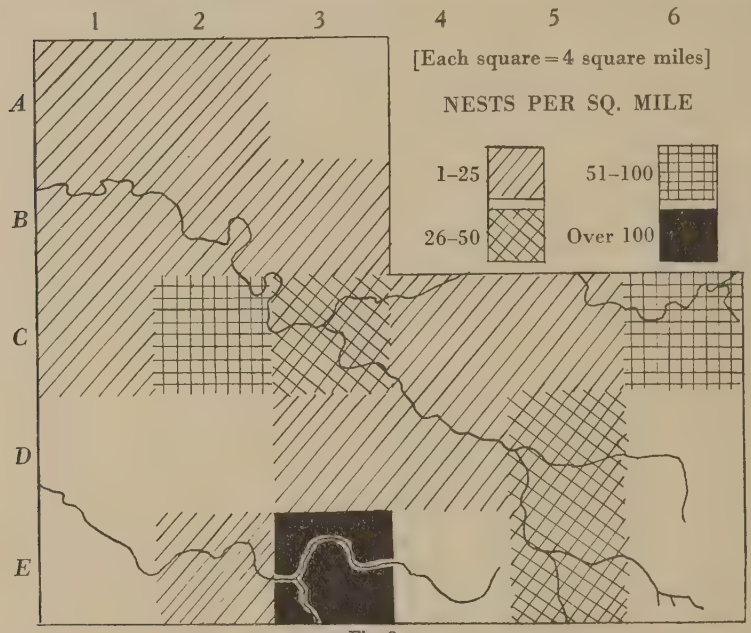


Fig. 3.

of Manchester with practically no open spaces, and *D* 6 and *E* 6 in the east are largely over 500 ft. above sea-level. The three squares *D* 1, *D* 2 and *E* 1 adjoining the lower Bollin valley are well wooded but the land is of a poor quality, and as previously stated, the river banks are steep, and do not provide water-meadows. A fairly large aerodrome is situated in *E* 4, and this no doubt accounts for the absence of nests in otherwise suitable country. There is a moderate-sized rookery just outside the area here, about 1½ miles to the south. The most densely populated squares are traversed by one of the two main rivers—the Bollin or the Mersey.

The Nicholsons (**2**) suggested that other species—jackdaw, carrion crow and lapwing, may affect the distribution of rookeries owing to competition for

nesting sites or food. It was not found possible to carry out any nesting census of these species but in no case did the jackdaw or carrion crow appear to be sufficiently plentiful to have any adverse influence on the rooks. In the Ringway area (squares *D* 1 and *D* 2) lapwings were observed to be particularly plentiful during a winter census in 1933, whilst few rooks were seen. Here also rookeries were completely absent, but, as previously remarked, it is more likely that this was due to the unsuitability of the country for feeding and nesting purposes than to competition with the lapwings.

The map showing the distribution of rookeries (Fig. 1) suggests that the area may have been populated from one or more "centres of dispersal" (**2**). The majority of the nests can be divided into five main groups, centred at Wilmslow, Cheadle, Poynton, Marple and Wythenshawe. As little evidence is available of the earlier histories of rookeries in this region, this must remain a surmise.

The average number of nests per sq. mile was 17·6; compared with other parts of the British Isles (**1**), this is rather low; but from Fig. 2 it will be seen that at least one-fifth of the area is built-up, so a more representative figure for the Cheshire plain would be higher. No exact figures are available for the area of agricultural land, but it is estimated, very roughly, that there is one rook's nest for every 20 acres of arable and permanent grassland.

4. Acknowledgements

We are greatly indebted to B. D. Norris and G. R. Vlies for much valuable assistance in making the actual census.

5. Summary

1. A census was taken of the rookeries in 96 sq. miles of land to the south of Manchester. 1691 nests were counted in forty-three rookeries, or 17·6 nests per sq. mile.

2. The main determining factors of distribution appeared to be altitude and the proximity of rivers with suitable meadowland.

3. The geological formation did not appear to influence the distribution, there being little geological variety in the district.

4. The rookeries were divisible into fairly well-defined groups, and it is possible that the district was first populated by diffusion from these centres.

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THE MARINE FOODS OF BIRDS IN AN INLAND FJORD REGION IN WEST SPITSBERGEN

PART 1. PLANKTON AND IN SHORE BENTHOS

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(*With 2 Maps*)

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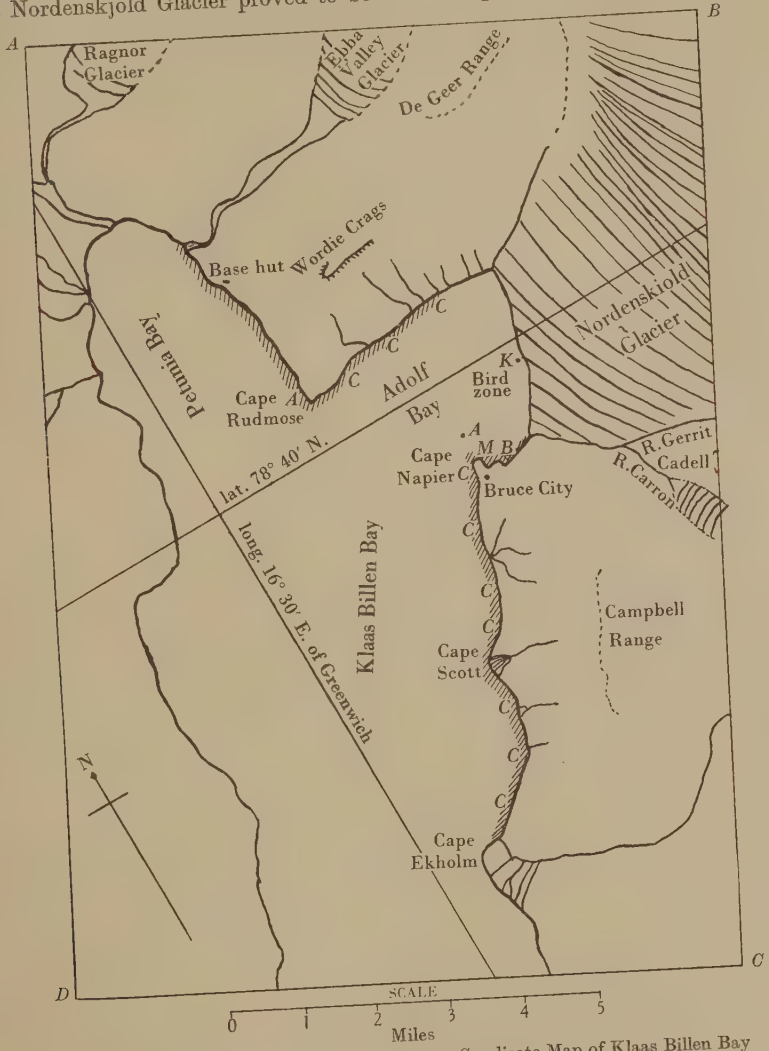
1. Introduction

As a result of previous Oxford University Expeditions to Spitsbergen ecological accounts of the terrestrial plants and animals have been published (**1**). In the summer of 1933 the Oxford University Arctic Expedition established a Base Camp at the head of Klaas Billen Bay in Icefjord, West Spitsbergen and observations on the marine fauna were carried out from a small whale boat equipped with an outboard engine. Bruce City was used as a base (see Map 1).

Since copious marine faunal lists for Spitsbergen waters have already been published as a result of the work of such large Expeditions as the Norwegian North Atlantic Expedition of 1876 78, the Russian *Ermak* Expedition of 1901, De Geer's Swedish Expedition of 1908, and the numerous Expeditions sent out from Norway in the *Torvik* and *Amauer Hansen*, no attempt was made to augment these lists in the time and with the equipment at our disposal. The main object of this paper is to give some account of the distribution and relative abundance of the marine animals in the surface plankton and shallow coastal region around Bruce City and note the chief species used as food by the large and essentially migrant bird population. My colleagues, C. H. Hartley and J. Fisher, will deal in detail with the feeding of the birds in Part 2.

Map 1 shows the region in which observations were made. The sea face of the Nordenskjold Glacier proved to be the focal point for the feeding birds



Map 1. Traced from the Scottish Spitsbergen Syndicate Map of Klaas Billen Bay by J. Mathieson. //// Region dredged over.

derived from a very considerable area. On 22 July 1933, a first visit was paid to the sea face of this glacier where we saw from 2000 to 3000 fulmars and kittiwakes feeding in a small zone of brownish-coloured water which was

apparently issuing from a cave in the glacier. Observations made on this feeding zone until 11 September 1933 showed that it remained as a large feeding zone until the birds began to migrate southwards at the end of August. The surface plankton in this zone contained, as the main food of the birds, the Euphausid, *Thysanoessa inermis*, which has never before been recorded in quantity at the surface of the sea in a non-spawning condition. The food of the birds away from the glacier is dealt with in the second section of this paper.

I am greatly indebted to the following for help: several members of the Zoology Department, of the British Museum (Natural History) for the identification of specimens[1]; Prof. Goodrich, F.R.S., for granting me the use of the Oxford University Table at Plymouth; Charles Elton for numerous points in the organization of this work; the Director of the Fisheries Laboratory, Lowestoft, for the loan of apparatus; A. R. Glen, organizer of the Expedition, for making the arrangements in connexion with the motor boat; and lastly but not least to my two colleagues at Bruce City, C. H. Hartley, and J. Fisher, for greatly relieving me of my share of camp work.

2. The glacier feeding zone

(*a*) *Situation and nature*

The sea face of the Nordenskjold Glacier is about 2 miles (3·2 km.) long. The feeding zone is situated near to the mid-point of this face. When it was first observed there were two ice caves in the glacier at sea-level, one in the northern part of the zone and the other in the southern. The northern cave fell away in the early part of August and revealed a rock outcrop which became more and more prominent as melting went on. The Sketch Plan (Map 2) shows these caves and the outstreaming current of detritus-laden water coming apparently from the south cave. There was generally a drift of water from the south-west which forced brash ice and small floes to the northern shores of Adolf Bay and deflected the outstreaming brown water to the north.

The bird-feeding zone occupied the inner part of the brown zone and the maximum density of the bird population occurred close up to the glacier face where, curiously enough, the chances of death through falling ice were greatest. We frequently saw birds killed through ice falls and "calving".

The observation of this brown detritus-laden water streaming away from the glacier suggested either that there was an upwelling of water generated by convection currents off the submerged face of the glacier which swept up detritus and the deep bottom-living Euphausid with it, or else that a glacier drainage stream emptied itself into the sea at this point and its detritus created a "light-tight" zone into which the Euphausids rose as a response to some environmental gradient. Two circumstances proved that the latter theory was correct. Firstly, as Table 1 shows, there was a good correlation between the

[1] The specimens are deposited there.

size of the brown zone and air temperature. The higher the temperature (as on 20 August) the greater the amount of melt-water produced by the glacier and the larger the tongue of brown water extending out into the bay. With a cold spell as on 1 September the reverse took place. Secondly, the temperature and

Map. 2. Sketch plan of bird zone and brown zone. (Soundings in metres.)

salinity observations taken at a point in the brown zone every week during our stay (see Appendix) show conclusively that a tongue of cold, dilute, sea water runs out from the glacier above the slightly warmer and more saline bay water and, furthermore, there is a correlation between salinity values and air temperatures. Thus, during the hot weather of 22 August the salinity was the lowest recorded.

Table 1. *Air temperatures and the size of the brown zone*

Date	Temperature: "High" if >10° C. "Moderate" if between 5° and 10° C. "Low" if <5° C."	Estimated size of brown zone
22 July	Moderate	Taken as a standard
25 „	„	Slightly larger but wind north-east
31 „	?	About the same as on the 25th
2 Aug.	High	Brown zone current stronger
5 „	Moderate	No change in size
9 „	„	Slightly larger, probably helped by north-east wind
10 „	Lower but not below 5° C.	Smaller than on the 9th. Sea calm
15 „	?	Smaller
18 „	Moderate	Small, extending about 70 yd. from glacier
20 „	High	Larger
22 „	„	Larger than on any previous occasion
26 „	Low	Medium
30 „	„	Small
1 Sept.	„	Very small
3 „	„	„
7 „	Moderate	Larger than on 5th, though still small
9 „	„	Slightly larger
11 „	Moderate to low	As on the 9th

(*b*) *Surface macroplankton*

Fulmars and kittiwakes formed the greater part of the birds in the feeding zone. They are surface feeders and dip their beaks about an inch below the surface and therefore the macroplankton available to these birds is essentially that in the very superficial layers.

The dominant forms in the surface macroplankton of the brown zone were:

Crustacea:
Calanus finmarchicus (Gunnerus).
Calanus hyperboreas (Kroyer).
Thysanoessa inermis (Kroyer).

Chaetognathi:
Sagitta elegans (Verrill).

Other forms which were obtained were:

Crustacea:
Euthemisto libellula (Mandt).
Hyperoche Kroeyeri (Bovallius).
Parathemisto oblivia (Kroyer).
} Only three specimens obtained.

Mollusca:
Clione limacina (Phipps).
Margarites helicina (Fabricius).
} Present on the border of the brown zone.

Tow-netting in the bird-feeding zone was particularly dangerous owing to the frequent falling of ice from the 80-ft. ice cliffs of the glacier. The most successful tow-netting was performed on 20 August by quickly towing a 40 cm. diameter medium mesh net to within 20 yd. of the glacier face on three occasions. A total catch of 325 *Thysanoessa* was made and assuming that a water column of length 100 m. had been traversed by the net, the Euphausid density in the surface layers works out at 26 individuals per cu. m.

From the numerous stomach examinations of fulmars and kittiwakes made by Hartley and Fisher it was clear that these birds principally eat *Thysanoessa inermis*. Occasionally a few specimens of *Sagitta elegans* and *Euthemisto libellula* were found; but on the average a fed bird must have eaten about 370 *Thysanoessa*.

(*c*) *Notes on the biology of* Thysanoessa inermis

The specimens were the *inermis* form of *Thysanoessa inermis* (Kroyer) described by Hansen (**2**). Of 292 measured specimens, 190 were females having a mean length of 24·5 mm. and 102 were males of mean length 25·0 mm. No breeding females with attached spermatophores were found and the shape of the size frequency curve suggests that the population was a homogeneous one derived from a spring breeding period.

During the examination of the mass of material clutched by the endopodites beneath the thorax of several *Thysanoessa*, broken pieces of Copepods and a small whole *Calanus* could be identified. There were also some diatoms and it is very probable that the *Thysanoessa* in the bird-feeding zone feed upon the abundant *Calanus* as well as on the diatoms sifted by the filter-feeding mechanism.

Thysanoessa inermis is an Arctic-Boreal species having its maximum occurrence in the Arctic Sea and the northern part of the Norwegian Sea. Robertson (**3**) records *Thysanoessa* as the main food of cod on the Bear Island trawling grounds. Ruud (**4**) describes the swarming and spawning of *Thysanoessa* at the surface of the sea off Möre in the west of Norway in the early spring, where it forms, along with the herring, the food of fin whales. In more southerly latitudes Lebour (**5**) records the finding of breeding *Thysanoessa* in the English Channel only in the deeper layers in spring. In the Gulf of Maine Bigelow (**6**) comments on its vertical distribution as follows "all the largest catches have been made in nets working at 40–80 m. deep. Thus it tends to congregate at about the same level as *Calanus*." It is curious to find that De Geer's Spitsbergen Expedition failed to obtain *Thysanoessa inermis* in any of the numerous tow-nettings which they made in Icefjord and even in Adolf Bay. With the trawl net, however, working at depths ranging from 118 to 230 m., 11 specimens were obtained.

From these references it is clear that the occurrence of non-breeding *Thysanoessa* at the surface of the sea is a remarkable phenomenon. What is its cause? *Thysanoessa* occurs most densely close in to the glacier where the detritus is most copious, the temperature is lowest and the salinity the lowest of any part of the brown zone. This suggests that there is a movement of *Thysanoessa* from the deeper layers in response to lower salinity, since surface illumination and temperature are comparable with those in the deeper layers.

Do feeding zones comparable to the one we observed occur elsewhere in Spitsbergen? Observations made by Fisher at the face of the Mittag-Leffler glacier in Wijde Bay throw some light on this (see Part 2 of this paper).

(*d*) *Phosphates in the bird zone*

Apparatus for the estimation of phosphates in sea water was taken up to Spitsbergen in order to observe the autumnal regeneration of these important nutrient salts in the upper layers where photosynthesis is carried on. Weekly estimations at various depths revealed the fact that the surface of the bird-feeding zone, in contrast to the rest of the upper layers of the bay, was rich in phosphates derived from the faeces of the feeding birds. A test of the diluted faecal matter from the rectum of a kittiwake showed it to be extremely rich in phosphates, and furthermore the fluctuations in the bird population near the glacier were correlated with the fluctuations in surface phosphate, as Table 2 shows. Of the 6 days, 22 August had the largest bird population and

Table 2. *Phosphate values as mg.* P_2O_3 *per cu. m. for the upper water layers near the glacier*

Depth in metres	8 Aug.	15 Aug.	22 Aug.	28 Aug.	5 Sept.	11 Sept.
0	11	8	12	5	0	9
5	2	2	7	3	4	4
10	0	0	4	6	7	5

5 September the smallest: then came in order of population size, 8, 15 and 28 August and 11 September together. On the last date there was some addition of phosphate to the surface layers through the beginning of the autumnal vertical circulation.

There is thus in the bird zone an interesting closed chain of events starting from the diatoms using phosphate and ending with the birds feeding on *Thysanoessa*, which feed on *Calanus* and other diatom feeders.

3. Marine ecology away from the glacier

(*a*) *Basic features*

Since diatoms are at the end of every food chain in the sea and diatom production is limited by the nutrient salts available in the upper layers where photosynthesis is carried on, some values for the phosphate content of the sea in the vicinity of Bruce City were obtained (see Appendix). Density determinations were made simultaneously to observe any discontinuity layers.

Weekly readings were obtained for the phosphate content and density of two 50-m. columns, one at point *A*, 2 miles from the glacier and half a mile off Cape Napier and the other at point *K*, 70 yd. from the glacier in the brown zone (see Map 1). The upper layers at *K* contain phosphate from the faeces of the feeding birds; whereas at *A* during the early part of August the upper 10 m. at least were completely depleted of phosphate and as the density determinations show, there was a discontinuity layer between the 10 and 15 m. levels. By 11 September the autumnal vertical turn-over was under way and the water showed a more uniform density profile. This agrees with the results

of Kreps (7) for the streaks of Arctic water in the Barents Sea, which show an earlier vertical circulation than the waters of Boreal origin. The values obtained at *A* are about half those obtained for Loch Striven (8) which is a comparable region in temperate latitudes. The lower values, however, do not seem to be reflected by a lower "fertility" as judged by the abundance of *Calanus* in the plankton.

Two phosphate determinations were made at the mouth of Adolf Bay on bottom samples:

Depth 90 m. Temperature −1·58° C. Phosphate 30 mg. P_2O_5 per cu. m.
Depth 125 m. Temperature −1·72° C. Phosphate 34 mg. P_2O_5 per cu m.

These again are relatively low values for the deep bottom water where phosphate reserves would accumulate.

(*b*) *Surface macroplankton*

The dominant members of the surface macroplankton in Adolf Bay and the upper part of Klaas Billen Bay were:

Coelenterata:
Cyanea capillata (Esch.). Present in swarms at the end of August and in September.
Aglantha digitale (Totton). Usually present but fluctuating greatly in numbers.

Ctenophora:
Pleurobrachia sp. Present on calm days at the surface of the bay.

Crustacea:
Calanus finmarchicus (Gunnerus).
Calanus hyperboreas (Kroyer). Always present, but very noticeable as large swarms at the end of July and in early August.
Mysis oculata (Fabricius). Very numerous in the shore zone.
Thysanoessa inermis (Kroyer). A few specimens obtained away from the glacier and near to icebergs late in August.

Chaetognathi:
Sagitta elegans (Verrill). Always present.

Mollusca:
Margarites helicina (Fabricius). Particularly present in large numbers on calm days in July.
Clione limacina (Phipps). Much less frequent than *Margarites*.

Of these only *Cyanea*, *Mysis*, *Thysanoessa* and *Sagitta* were found to be eaten by birds.

When food was scarce at the beginning of September owing to the disappearance of the glacier feeding zone, fulmar petrels were seen to be pecking at the large brown jellyfish, *Cyanea*, which appeared in swarms in the bay at the beginning of September. Further examination of some of these birds showed that the jelly was actually passed into the stomach.

Mysis oculata occurred in the shore zone particularly where small streams passed out into the sea and low salinity values such as 27 $^{\circ}/_{\circ\circ}$ were recorded. A few specimens were occasionally found in the stomachs of fulmars, kittiwakes, and eider ducks, but Arctic terns, Mandt's guillemots, and puffins contained greater quantities and evidently selected *Mysis* as a food.

At the end of August and in September it was noticed that fulmars occurred in small groups around icebergs and on one occasion they were noticed to be flocking on a patch of water off Rudmose Point. A tow-netting close in to one berg revealed the presence of a few *Thysanoessa*. A few specimens of *Sagitta elegans* occurred in the stomachs of some fulmars. For comparison with the work of Russell (**9**) on the biology of this species in the English Channel observations were made on the size and gonad condition of specimens obtained in the tow-nettings.

(*c*) *Notes on the biology of* Sagitta elegans

The specimens correspond with the large variety *Sagitta elegans arctica* as defined by Ritter-Zahony (**10**). The species noted by De Geer's Expedition in Icefjord (**11**) was incorrectly given as *Sagitta bipunctata* (Quoy & Gaimard) a species which is now considered by Huntsman (**12**) to be essentially a warm water one barely reaching 25 mm. in length.

1092 specimens taken from catches obtained at various times were measured and samples from each catch stained in alum carmine and mounted for gonad examination. They showed two stages: (1) Very immature. In the larger specimens the testes had started to grow to the hind end of the tail. There was no sign of any ovarian tissue. Length of specimens ranged from 5 to 23 mm. (2) Immature. The tail filled with mature sperm. Ovaries present but all the oocytes small and alike. Length of specimens ranging from 17·5 to 40 mm. There were no fully ripe individuals with large gelatinous eggs in the trunk cavity and no "spent" specimens.

The bulk of the catches consisted of the small, very immature individuals together with a lesser number of large immature forms. The gonad condition of the latter suggests that they would be ready to breed towards the end of September before the freezing over of the fjord. The small individuals were probably the result of prolonged spring breeding, beginning perhaps late in May after the sea ice had broken up. It is probable that there are two breeding periods per year in these inner fjord waters, one in the late spring and one in the late autumn, and that the animals in each brood take a year to reach maturity. This is in some agreement with Kramp's (**13**) observations for the same species in the western coastal waters of Greenland about latitude 76° N. He states, as a result of examination of specimens taken in July and August, that "at most stations small and full-grown specimens were found together which indicate that the breeding period in Greenland waters extends over a considerable space of time, though the relative number of different groups at different times seems to indicate that the bulk of the specimens breed in the autumn".

(*d*) *The inshore benthos, including fishes*

The shaded portion in Map 1 shows the extent of the examination of the bottom living animals. A naturalist's dredge was used and depths up to about 25 m. were sampled. This is quite sufficient for obtaining the benthos available

as food for the diving birds. In nearly all the area examined the shore line descends very rapidly owing to the fjord formation of the bays, so that this shallow inshore zone is a very narrow one. Furthermore, ice action prevents the permanent occupation of the intertidal and shallow water zones by any but a few small forms such as the worm *Lumbricillus aegialites*. The greater part of the region examined had a bottom that was shingle inshore, but a mixture of varying proportions of sand and grey mud in deeper water. This region is marked as *C* in Map 1. The remains of a line of erratics to the south of Adolf Bay form a boulder zone marked as *B* where there was a sandy bottom. To the east of Cape Napier there was a mass of decaying vegetation marked as *M*. Off Cape Rudmose there was a very distinct Laminarian zone with numerous small boulders close inshore; this region is marked as *A*. The fauna was listed as follows:

Annelida:

Polychaeta.

Nereis pelagica (L.). From *A*.
Nereis zonata (Malmgren). Very common in *C*.
Lumbrinereis fragilis (O. F. M.). Found in *C*.
Nepthys ciliata (O. F. M.). Found in *C*.
Harmothöe imbricata (L.). Very common in *C*. Eaten by Mandt's guillemot.
Euchone analis (Kroyer). A small worm in a black tube very dominant in *M*.
Chone infundibuliformis (Kroyer). Found at about 15 m. in *C*.
Terebellides stroemi (Sars.). Found in *C*.
Ammotrypane aulogaster (Rathke). Common in *C*.
Polycirrus medusa (Grube). A small worm fairly common in *C*.
Capitella capitata (Fabricius). One specimen only from off Cape Napier at about 15 m.

Oligochaeta:

Lumbricillus aegialites (Stephenson). Very numerous under stones in parts of the intertidal zone.

Crustacea:

Balanus porcatus (Da Costa). On the boulders in *B*.
Caprella septentrionalis (Kroyer). Numerous at 10 m. in the weed off Cape Napier.
Anonyx nugax (Phipps). Common in *C*. Eaten by eider ducks.
Gammarellus homari (Fab.). In *B*.
Gammarus locusta zaddachi (Sexton). Common in *B*.
Pseudalibrotus littoralis (Kroyer). Fairly common in *C*. Eaten by terns, fulmars and eider ducks.
Spirontocaris gaimardii (H. M. Edw.). Common in *C*. Eaten by eider ducks and guillemot.
Eupagurus pubescens (Kroyer). Common in *C*. Eaten by eider ducks and Mandt's guillemot.
Sclerocrangon boreas (Kroyer). Fairly common in *C*.
Hyas araneus (L.). Very common in *C*. Eaten by eider ducks and Mandt's guillemot.

It can be seen that all the larger species of Crustacea form part of the food of the diving birds.

Mollusca:

Buccinum glaciale (L.), *B. undatum* (L.): Found in small numbers in zones *M* and *C*. Some spawn found near Cape Scott. Apparently not used as food by any birds.
Lacuna crassicor (Montagu). Found attached to Laminaria in coastal waters. Eaten in small numbers by eider duck.
Liocyma fluctuosa (Gould). In the mud especially at *M*. Eaten by eider duck.
Serripes groenlandicus (Gould). In small numbers off Cape Napier. Not found in any birds' stomach contents.
Astarte fabula (Reeve), *A. elliptica* (Brown), *A. borealis* (Schum.): Three closely allied species found in the mud of the whole of the coastal zone. *Astarte borealis* was the most numerous of all the Mollusca and was constantly found in the stomachs of eider duck and Mandt's guillemot along with *A. fabula* and *A. elliptica*.
Tonicella marmorea (Fab.), *Ischochiton albus* (L.): Found on Laminarian holdfasts. Not found in birds' stomachs.

The mud-living Lamellibranchs are the most popular foods of the diving birds.

ECHINODERMATA:

A Holothurian of the genus *Myriotrocus* forms part of the bottom fauna in the "debris" zone off Cape Napier. It was not found in the food of any bird.

TUNICATA:

Rhizomolgula globularis (Pal.). Common in the mud off *B*. Not eaten by birds.

FISHES:

Leptoclinus maculatus (Fries). A butter fish, several specimens of which were taken from Mandt's guillemots and puffins shot in the bay.

Liparis liparis (Linn.). A sucker fish which is very common in the inshore zone from Cape Napier to Cape Scott. Not found in any birds' stomachs.

Boreogadus saida (Lepech). Young specimens of the Arctic cod were found in the stomach of the puffin and seal.

Myxocephalus scorpius (Linn.) } Bullheads taken in the dredge in zone *C* but not found
Gymnocanthus tricuspis (Reinh.) } in any stomach contents.

4. SUMMARY

Some account is given of the marine ecology of an inner fjord region in West Spitsbergen. The surface macroplankton of the fjord and the bottom fauna of the shallow coastal region around Bruce City are described. A densely populated bird feeding zone at a point where a drainage stream issued from the Nordenskiold Glacier was found to contain enormous numbers of the Euphausid, *Thysanoessa inermis*, which was the principal food of the birds. Data on the size and breeding of *Sagitta elegans* and *Thysanoessa inermis* are given. Comparatively low phosphate values were recorded for the sea at various depths in the fjord and conditional density determinations show the beginning of the autumnal vertical circulation early in September.

APPENDIX

Hydrography and plankton technique

Water samples were obtained by means of Nansen reversing water bottles. Temperature determinations were made with reversing thermometers attached to the water bottles and the temperature correction of the main thermometer made from the *Standard Oceanographical Tables* by N. N. Subow (Moscow, 1931). The salinity estimation was carried out according to the method of Oxner & Knudsen given in Bulletin No. 3 of the *Commission International pour l'exploration de la mer Méditerranée* (1920), using the standardized instruments supplied by the Copenhagen Hydrographic Laboratory. Conditional density calculations were made by the use of Knudsen's Tables quoted by Subow. Phosphate estimations were carried out by the method given by Atkins (1923) in the *Journal of the Marine Biological Association* 13: 144.

Conditional density

By calculating the conditional density of the sea water at the various depths at which salinity and temperature observations were made the stratification of the 50-m. column could be obtained. The figure given for conditional

Table 3. *At point A off Cape Napier. Depth of bottom 75 m.*

Date	Depth in m.	Temp. °C.	Salinity °/oo	Conditional density σ_t	Phosphate P_2O_5 mg. per cu.m.
Aug. 8	0	6·52	—	—	—
	5	—	—	—	—
	10	6·33	—	—	—
	15	—	—	—	—
	20	—	—	—	—
	25	3·15	—	—	—
	50	0·03	—	—	—
Aug. 15	0	5·29	30·10	23·79	0
	5	6·13	30·43	23·96	0
	10	6·05	30·84	24·27	0
	15	5·95	31·00	24·43	0
	20	2·95	33·04	26·35	9
	25	1·83	33·73	26·98	11
	50	0·22	34·38	27·61	14
Aug. 22	0	7·40	27·63	21·60	0
	5	6·11	28·95	22·80	0
	10	5·23	30·35	23·99	0
	15	1·78	32·99	26·40	11
	20	1·84	33·60	26·88	12
	25	1·66	33·75	27·01	11
	50	0·40	34·09	27·37	17
Aug. 28	0	4·95	29·61	23·44	0
	5	4·83	29·67	23·49	0
	10	3·89	32·70	25·99	0
	15	2·20	32·90	26·31	6
	20	2·56	33·46	26·71	5
	25	2·83	33·57	26·78	9
	50	0·57	34·29	27·52	14
Sept. 5	0	3·29	31·02	24·72	0
	5	3·57	31·55	25·10	0
	10	3·80	32·81	26·09	0
	15	3·37	33·24	26·48	6
	20	2·94	33·58	26·77	7
	25	1·55	33·60	26·90	8
	50	0·29	34·34	27·58	17
Sept. 11	0	1·92	31·44	25·16	0
	5	3·93	32·59	25·91	4
	10	3·82	32·79	26·07	5
	15	3·43	33·17	26·41	6
	20	3·37	33·26	26·48	6
	25	2·83	33·46	26·69	8
	50	0·25	34·11	27·39	13

density is related to the actual figure for the density of the sea water (referred to that of distilled water at 4° C.) in the following way: suppose the conditional density is recorded as 23·72, then the actual density is 1·02372. The method of calculation of the conditional density is as follows: suppose the salinity titration has resulted in a chlorine value of 16·425. From Knudsen's Tables the corresponding value for the specific weight of the water at 17·5° C., $\rho_{17\cdot5}$ is 22·66. Suppose the temperature of the water sample was 2·15° C. Then the Knudsen correction, E, for water at 2·15° C. and of specific weight 22·66 is $-1\cdot06$ and conditional density $=\rho_{17\cdot5}-E=22\cdot66+1\cdot06=23\cdot72$. Salinity or temperature determinations alone cannot show up the stratification of the

water, but a glance at the Tables shows the sharp discontinuity between the upper 15 m. and the deeper waters in early August, which gradually disappears until by 11 September there is a fairly uniform transition in density between the surface and 50 m. depth. Nutrient salt regeneration in the surface layers then starts to take place.

Table 4. *At point K in the brown zone. Depth of bottom* 55 *m.*

Date	Depth in m.	Temp. °C.	Salinity °/oo	Conditional density σ_t	Phosphate P_2O_5 mg. per cu. m.
Aug. 8	0	2·15	29·67	23·57	11
	5	3·70	30·23	24·05	2
	10	5·45	31·22	24·66	0
	15	5·20	—	—	2
	20	4·46	31·92	25·33	4
	25	2·27	33·30	26·62	7
	50	−0·93	34·40	27·68	14
Aug. 15	0	2·3	29·88	23·88	8
	5	2·71	30·17	24·08	2
	10	5·42	30·68	24·23	0
	15	5·45	30·88	24·36	0
	20	1·35	31·69	25·39	5
	25	1·26	33·62	26·93	9
	50	−0·15	34·36	27·61	14
Aug. 22	0	1·18	28·08	22·52	12
	5	1·42	28·21	22·60	7
	10	2·40	29·16	23·31	4
	15	3·88	30·39	24·18	0
	20	0·69	33·44	26·83	11
	25	1·54	33·62	26·91	12
	50	0·22	34·07	27·36	16
Aug. 28	0	3·50	29·65	23·61	5
	5	3·90	30·05	23·89	3
	10	1·27	30·46	24·41	6
	15	2·80	33·10	26·41	6
	20	3·20	33·66	26·83	7
	25	0·67	33·71	27·06	13
	50	−0·04	34·22	27·50	15
Sept. 5	0	2·60	30·77	24·57	0
	5	0·98	31·65	25·38	4
	10	2·59	32·59	26·03	7
	15	2·80	33·15	26·45	7
	20	2·95	33·49	26·70	9
	25	1·18	33·69	27·00	12
	50	−0·18	34·25	27·53	17
Sept. 11	0	1·60	32·05	25·67	9
	5	3·22	32·99	26·30	4
	10	3·74	33·31	26·51	5
	15	3·54	33·30	26·51	6
	20	3·00	33·30	26·55	8
	25	2·29	33·33	26·65	11
	50	−0·21	34·14	27·44	13

Plankton technique

Plankton hauls were made at about 90 places in Adolf Bay, Petunia Bay, and the westerly part of Klaas Billen Bay as far south as Cape Ekholm between 10 July and 13 September 1933. Material from 45 hauls was preserved and brought back to England. Most of the collecting was done by

means of a 60-mesh conical net of 40 cm. diameter towed behind the motor boat. A 60-mesh International pattern net of 1 m. diameter was used at first but it was unfortunately lost in a rough sea on 14 July. Some vertical hauls were made by means of a small Apstein net of 25 cm. opening which was of 180 mesh. A 60-mesh net with a rectangular mouth, measuring about 1 m. by 25 cm. was used for collecting in the shallow coastal zone.

It was soon obvious that four zones existed in the surface waters of the region examined:

1. The offshore waters of Klaas Billen Bay and Adolf Bay, rich in *Calanus* and *Sagitta*. Early in August the surface waters were thick with *Calanus* in certain places on calm days.
2. The bird zone characterized by the presence of *Thysanoessa* and larger specimens of *Sagitta*.
3. The inshore waters with numerous *Mysids*.
4. The muddy shallow waters of Petunia Bay with a very sparse plankton.

Most of the collections were made in zones 1 and 2. Vertical and deep horizontal hauls were also made in zone 1 in search of *Thysanoessa* but without success.

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THE MARINE FOODS OF BIRDS IN AN INLAND FJORD REGION IN WEST SPITSBERGEN

PART 2. BIRDS

By C. H. HARTLEY and JAMES FISHER

(*With* 1 *Graph and* 1 *Map*)

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1. Introduction

This paper (Part 2) is an attempt at an intensive study of food supply and feeding habits in a simplified bird community, in close conjunction with the series of marine biological investigations during the Oxford University Arctic Expedition of 1933. West Spitsbergen has been frequently visited by ornithologists, and much general information is available concerning the distribution and nesting habits of the bird population. With the exception, however, of the work of the Oxford Expedition of 1924 (**13**), practically no work has previously been done on food in this district.

Apart from a short visit to Wijde Bay for the purposes of comparison, the whole work was carried out on the marine-feeding section of the bird population in the Klaas Billen Bay area. As the number of species to be dealt with is small, Arctic regions in general are ideal for intensive ecology. The problem in the barren "Inner fjord zone" of west Spitsbergen (**16**), appears at first sight to be simplified almost to the point of extinction; but the situation is complicated by the peculiar effect on the food supply of a glacier with a sea frontage. This effect was studied in some detail, and plays an important part in the economy of the district.

Except where otherwise stated, all observations were carried out in an area comprising the whole of Adolf Bay and the small bays along the coast between Cape Napier and Cape Ekholm; thus they covered the same district as the marine biological investigations.

2. The bird population

An account of the general avifauna of Spitsbergen will be found in the results of the three previous Oxford Expeditions (**6**, **11**, **13**). The nesting population of the area studied (Petunia Bay and Adolf Bay, Map 1), was abundant neither in species nor in numbers; the number of birds feeding in the area was by contrast large. The species studied fall into three general ecological groups.

Surface feeders:

Kittiwake, *Rissa tridactyla tridactyla* L.
Arctic tern, *Sterna paradisea* Brünn.
Fulmar, *Fulmarus glacialis glacialis* L.
Glaucous gull, *Larus hyperboreus* Gunn.
Ivory gull, *Pagophila eburnea* Phipps.

Divers:

Northern eider, *Somateria mollissima borealis* Brehm.
Brünnich's guillemot, *Uria lomvia lomvia* L.
Mandt's guillemot, *Uria grylle mandtii* Mandt.
Little auk, *Plotus alle* L.
Spitsbergen puffin, *Fratercula arctica naumanni* Norton.

Scavengers, predators etc.:

Fulmar.
Glaucous gull.
Ivory gull.
Arctic skua, *Stercorarius parasiticus* L.

In addition, work was done on the ringed seal, *Phoca hispida* Schreber which was plentiful in the neighbourhood of the Nordenskjold glacier, and on the purple sandpiper, *Calidris maritima maritima* Brünn., the only wader of more than casual occurrence, which fed generally in the intertidal zone.

It is necessary at the outset to give a brief account of the distribution of local nesting sites of these species.

Kittiwake. With the exception of a small colony on a cliff up the Horbye glacier, reported by a survey party, kittiwakes did not nest anywhere in the area under observation. The chief colonies were situated on the south coast of the Fjord about 30 miles from the Nordenskjold fishing zone.

Arctic tern. A well-established nesting species, colonies being found at Bruce City, at the mouths of the rivers Ebba and Gerrit, and at the feet of Mts Pyramid and Triplex. Further down the bay there was a large colony at Anser Island. The colonies in general were not large and the nests were somewhat scattered.

Fulmar. By far the most plentiful nesting species in the district, nesting in numbers on all suitable crags both on the coast and at varying distances inland. The sledge party of the Oxford Expedition of 1921 reported a colony on Mt Terrier, some miles up the Nordenskjold glacier, and flight line observations indicate that this site is still occupied. Further down the bay fulmars were plentiful on the cliffs beyond Phantom Point.

Glaucous gull. Nested in numbers on the cliffs below Phantom Point. Not found nesting in Adolf or Petunia Bays.

Northern eider. No eider holms proper existed in the district, but the species was well represented, 15 broods being noted on 21 August between the Nordenskjold and Cape Ekholm.

Brünnich's guillemot. Did not nest anywhere in the head waters of Klaas Billen Bay, the nearest colonies being found on the cliffs beyond Phantom Point.

Mandt's guillemot. Nested in limited numbers on some low cliffs flanking the sea at the foot of Wordie crags, between the Base Hut and Rudmose Point. More plentiful on the cliffs beyond Phantom Point.

Little auk. Nested in large numbers on the cliffs beyond Phantom Point.

Spitsbergen puffin. Nearest nesting sites the cliffs beyond Phantom Point, and Anser Island.

Arctic skua. Distributed evenly round the coast of Klaas Billen Bay, about one pair to every 2 or 3 miles.

Purple sandpiper. Generally distributed all round the coast at the head of Klaas Billen Bay, about two pairs to a mile, though rather irregularly spread.

3. Food supply, part 1: surface feeders

The glacier feeding zone. The presence of a feeding zone at the sea frontage of the Nordenskjold glacier was first suspected on 10 July, when a party from the base hut, visiting Bruce City, noted numerous flocks of kittiwake heading towards the glacier on a regular flight line. Observations from the shore showed large numbers of birds resting on the water in the vicinity of the two ice caves (Part 1, Map 2), and since on further investigation this flocking appeared to be a permanent feature, not previously recorded from the Arctic, the biological party was transferred to Bruce City on 16 July for a detailed investigation.

Typical appearance of the bird zone. The following account applies to the zone up to the last week in August.

The bulk of the birds present were kittiwakes, the normal number appearing to be in the neighbourhood of 2000. The remainder of the pack was composed of fulmars, whose numbers fluctuated considerably, the normal being from 500 to 700. The pack extended from the mouth of Cave *B*, where the concentration was greatest, to a point beyond the mouth of Cave *A*, being roughly oblong in shape, about 60 yd. long and 30–40 yd. deep. The birds at the foremost end of the pack were close up to the face of the glacier, and often inside Cave *B*; the position of the rear of the pack varied with the direction of the

stream flowing out of the glacier at Cave *B*. The limits were always sharply defined, the birds being closely crowded together. It was interesting to note that within the pack a very definite segregation of species was apparent, the fulmars being always found on the right of the pack at the mouth of Cave *B*, and often tailing away in the opposite direction to the kittiwakes.

When feeding, the birds rested on the water, swimming actively in the strong current running out of Cave *B*, and making periodic pecks at their prey. When the current had carried them down to the tail of the pack, they usually rose from the water, alighting again at the mouth of the cave. Feeding was accomplished by a rapid dart of the head, the birds seldom moving far from their position in the pack, or immersing the head beyond the base of the bill. The process of hovering and dipping was never noted in the bird zone, though in such kittiwakes as were observed feeding in other parts of Klaas Billen Bay this appeared to be the normal method of capture. "Up-ending" was noted occasionally with fulmars, but never with kittiwakes. The food obtained must therefore have been taken from the extreme surface layer; a fact primarily due to the abundance of supply and the turbidity of the water in the bird zone.

Investigations on a quantitative basis were carried out from 16 July to 12 September, with the object of finding out the nature of the demands made by the bird population on the plankton, and in an attempt to provide corroborative evidence for the explanation of the swarming of plankton in this particular region. The following problems were studied: (1) Nature and quantity of food taken. (2) Rate of feeding. (3) Number of birds concerned in the particular zone. (4) Amount of plankton removed. (5) Existence of similar conditions at other glacier faces.

(*a*) *Food of zone-feeding kittiwakes*

The following observations were carried out on birds returning from (and, in a few cases, feeding in) the bird zone. In all 227 stomachs were examined, 68 proving empty. The qualitative results of the remaining 159 are given below, with brief notes.

Thysanoessa inermis Kroyer.

159 records. This was by far the most important item of food, the remainder being almost insignificant by comparison. The highest stomach content was 1038, and the average 331. The quantitative results will be dealt with more fully in a later section.

Mysis oculata Fabricius.

Eight records, one of 94, the others all less than 10. This crustacean is very common in the inshore zone, but occurs generally in the area, judging by puffin and guillemot records.

Euthemisto libellula Mandt.

Sixty-seven records, all under 20 except for one of 75 and one of 211. Records for other species indicate that it is generally distributed in the area, though not normally in the inshore zone. Although it is sometimes obtainable in large numbers it cannot be regarded as a major item of diet.

Harmothöe imbricata L.

The paragnaths of this worm were obtained on eight occasions early in the season. On no occasion were any other parts of the body identified. It is to be presumed that the worms were taken at the surface during a free-swimming heteronereid phase, but it is impossible to say how long the paragnaths had been retained in the pyloric end of the bird's stomach.

Fish.

Four records. In general, fish are not plentiful in the area, and form an insignificant part of the kittiwake diet. The reverse is, however, the case on the north coast of Spitsbergen, outside the Inner Fjord zone (Montague (**13**)).

Vegetable matter.

We found only one case with a trace of vegetable matter in the stomach.

Observations by other authorities.

Montague also records kittiwakes taking the black pteropod *Clio*. In Greenland Nicholson (**15**) has observed the birds fishing like terns, while at Cape Boheman, in Ice Fjord, Van Oordt (**18**) saw a kittiwake chase a tern and deprive it of food as does a skua. Le Roi (**10**) has recorded whale carrion as food. Belopolskij (**1**) in 1927–8, during his journeys along the Kola meridian, made intensive counts of kittiwake and fulmar numbers and recorded a correlation between these and the abundance of Pteropoda in the surface layers of the sea.

(*b*) *Quantitative results for* Thysanoessa

Fig. 1 gives the frequency of *Thysanoessa* in the stomachs analysed. Where digestion had set in, numbers were estimated by counting the pairs of eyes, which remained united after the rest of the body had become soft. It will be noted that the maximum frequency is for completely empty stomachs.

Significance of the empty stomachs.

All analyses included in the frequency chart were carried out on birds returning from the zone to their colonies, and were concluded on 18 August. The first young bird of the year was obtained in the zone on 15 August, but young did not begin to appear in numbers till 20 August. It may be inferred that, before 18 August, the young were still being fed in their colonies.

Normally the kittiwakes left the bird zone in small flocks, and headed straight for the colonies without making any intermediate halts. It was, however, noted that there was always a certain number resting on the glacier face to the right of the zone. It is probable, therefore, that the birds with empty stomachs had been digesting on the glacier before their return to roost, and furthermore, that the total of empty stomachs provides a minimum measure of the proportion of non-breeders and unsuccessful breeders among the kittiwakes frequenting the zone. Nicholson (**15**) in Greenland, has observed parties of 100 or more "resting" on icebergs.

Sex ratio.

Of all the birds we sexed there were 107 males to 104 females, giving then a 50/50 sex ratio. In nearly all these in mid-July and onwards the gonads were not fully developed and had probably therefore regressed. There was locally quite obviously a scarcity of breeding ground (see (*a*)), and perhaps it would not be over bold to suggest that the cause of the number of non-breeders is the fact that, as Lack (7) suggests with the arctic tern, the gonads had regressed before nesting sites had become available for some of them. A fact

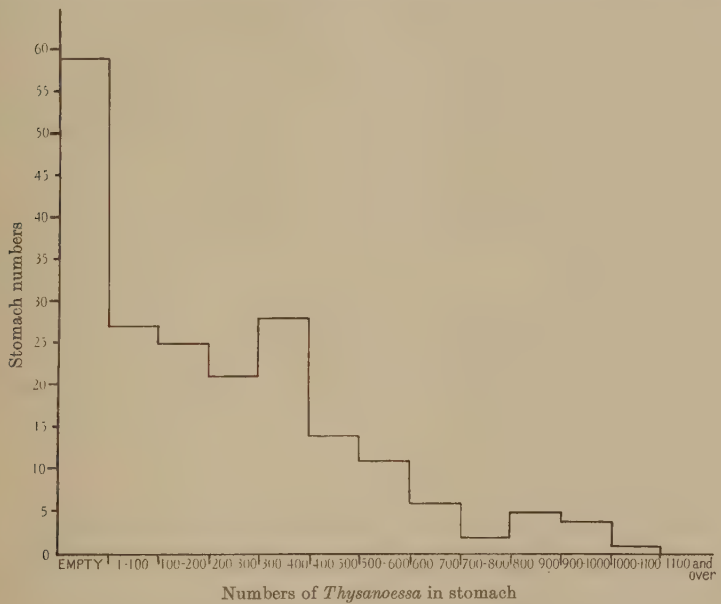


Fig. 1. Frequency of *Thysanoessa* content in the stomachs analysed.

which is possibly of some importance is that we found no difference in the development of the gonads of those with empty stomachs compared with those which had the remains of incubation patches or which were carrying food for their young in their gullets.

Minimum kittiwake meal.

Neglecting empty stomachs, it is found that 144 birds sampled give a mean removal of 331 *Thysanoessa* per bird/trip to the glacier. This figure is essentially a minimum, since it does not allow for digestion either during the meal or during a potential post-prandial resting period on the glacier.

For each analysis a note was made with regard to the position in which the food was found (stomach only, gullet only, stomach and gullet), and to the

extent to which digestion had proceeded in the stomach contents. Taking out 24 analyses in which the gullet was empty and the stomach content mainly or partly digested, a corrected figure of 371 is obtained. Birds with empty stomachs and food in the gullet have not been taken out, in view of the fact that the young were being fed during this period.

(c) *Kittiwake numbers and rate of feeding*

Bird visits per day.

A mean figure was obtained by half-hour counts of the number of birds leaving the bird zone, taken every 6 hours over a period of 9 days, from 15–23 July. The counts were made from the end of the south-west lateral moraine of the glacier, the principal flight lines lying over or near to this point. An attempt to correlate these counts with air temperature, wind strength and direction, and ice conditions, failed, probably owing to the use of too small a time interval. A correlation on a much broader scale certainly does exist in the case of air temperature (see Part 1 of this paper and below). Feilden (4) records a slight falling off of activity at midnight, but our results do not confirm this.

The figure arrived at was 325 (max. 508, min. 98). The daily number is therefore approximately 15,600.

It was observed that the flight-lines and numbers of birds flying remained more or less constant throughout the latter part of July and up to the last week of August. Our daily figure is therefore used for calculations covering this period.

Daily Thysanoessa *removal.*

The average daily bird/visits we have shown to be 15,600, and the mean removal, using the corrected stomach content, is 371 per trip. Hence the mean number of *Thysanoessa* removed by kittiwakes alone per day from the zone was approximately 5,778,000, i.e. 67 per sec., as the birds fed continuously throughout the 24 hours.

Rate of feeding in the zone.

This was estimated by timing birds in the centre of the pack for three packs. A series of observations was thus obtained covering the same period as the hydrographical investigations, and we hoped to find a correlation. On statistical examination the figures proved to be normally distributed about day means, but the differences between day means were found to be insignificant as a whole owing to the large standard error. Ten determinations of peck intervals were made at various hours on each of 10 different days in August, giving 100 determinations in all. From these we calculated the mean peck interval to be 19 sec. to the nearest second. Given a mean removal of 67 per sec., this gives an estimate of the number of birds actually feeding in the

zone at any one time of 19×67, i.e. approximately 1300. From our own observations we concluded that the actual mean population was more than this—in the neighbourhood of 2000. Accurate counts in the bird zone were impossible owing to the numbers and mobility of the birds present. Approximate numbers were obtained by general estimation, checks being made by counts done on enlarged photographs.

The difference between these two figures may be regarded as an indication of the efficiency of the birds' feeding, the figure 1300 being calculated on the assumption that a bird ate one *Thysanoessa* per peck. It must be borne in mind however that the figure of 2000 is an approximation.

Finally, we can find the approximate time spent actively feeding by the product of the mean peck interval and the mean stomach content; this is 371×19 sec., i.e. almost exactly 2 hours, or rather more if the efficiency is taken into consideration.

(d) Correlations

The correlation between kittiwake numbers and phosphate content in the water of the bird zone has already been referred to in Part 1 of this paper.

For correlation between bird numbers and air temperature reference is made to Table 1 in Part 1 of this paper. On 22 August, after 2 hot days, the maximum number of birds was recorded. A cold spell started on 26 August. On 28 August bird numbers began to decrease and by 3 September the bird zone was deserted. A mild spell began on 7 September and by 9 September 500 kittiwakes had returned.

(e) Extra-zonal feeding in Adolf Bay

Before the beginning of September kittiwakes were only once seen feeding away from the glacier. On 4 August two kittiwakes were seen feeding with 30 fulmars off Bruce City. The fulmars were eating *Sagitta* but we failed to shoot a kittiwake. On 1 September 40 kittiwakes were seen hovering and dipping off Cape Rudmose, and a female shot contained 54 *Thysanoessa* and 237 *Euthemisto*. Another female shot on 5 September from a pack of 40 in the same place contained a few *Thysanoessa* and a small fish (unidentified). From the rarity of extra-zonal feeding we conclude that food was not normally available in any quantity in the surface layer, a fact which is in agreement with the results of plankton tow-netting.

In short, perhaps the glacier melt-water alone determines the presence of kittiwake in the Inner Fjord zone.

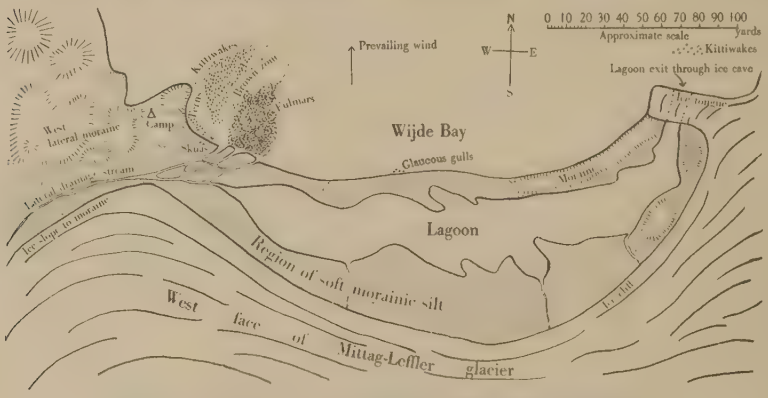
(f) Feeding zone at face of Mittag-Leffler glacier, Wijde Bay

On 5 September one of us (J. F.) made a short journey with a sledge party over the Mittag-Leffler glacier to the south end of Wijde Bay. The presence of a feeding zone at the face of this glacier was immediately noticed (Map 1).

Appearance and ecology of zone.

At the west end of the 2-mile face of this glacier the lateral moraine curved round between the edge of the glacier and the shore of the bay. The morainic matter was exceptionally soft and sedimentary, and was traversed by the lateral drainage stream of the glacier. At the mouth of this stream sediment was carried out some yards out into the bay, and it was in this region that *Euthemisto libellula* was found swarming in vast numbers. In some places it was so thick that a swarm of living and dead crustaceans could nearly always be found on the margin of the water, sometimes an inch or more in thickness.

Large numbers of birds fed here; they were never so numerous, however, as at the face of the Nordenskjold glacier. The fulmars here slightly outnumbered



Map 1. Feeding zone at face of Mittag-Leffler glacier, Wijde Bay.

the kittiwakes in the zone, and the average numbers feeding were about 300 fulmars and 250 kittiwakes. In addition a flock of sometimes 400 kittiwakes was always present "resting" on the shore by the lagoon. Arctic terns were present also, sometimes up to 60, while three pairs of skuas hung about the region and attacked kittiwakes at irregular intervals. Some way away from the zone a flock of about 20 glaucous gulls were feeding by the shore, apparently on *Euthemisto*. Five fulmars, nine kittiwakes, one tern, two skuas, and a young glaucous gull were shot and found to contain *Euthemisto* alone. Seals were apparently absent.

The observer also rowed across the face of the glacier but saw no close-in feeding zones, except at the mouth of the ice-cave (see Map 1) where the lagoon communicated with the open sea. Here a small group of kittiwakes often fed. At the lateral moraine at the eastern end arctic terns, kittiwakes, and seals were seen feeding. There was no definite drainage point and the birds fed in no regular groups. Sampling had the following results:

Kittiwake. Six examined.
Euthemisto in one.
Mysis in six.

Arctic tern. One examined.
Thysanoessa.
Euthemisto.

Seal. One examined.
Thysanoessa.
Euthemisto.
Gammarus locusta zaddachi Sexton.
Spirontocaris gaimardii H. M. Edw.

(*g*) *Fulmar*

As already stated, fulmars were extremely abundant in the Adolf Bay district, and formed a permanent, though varying proportion of the bird zone. Their colonies were scattered all round the neighbouring cliffs, and their feeding habits were both spasmodic and diverse; it was hence impossible to study them on the same basis as the kittiwakes, the consistency of the latter in flight lines and feeding localities rendering them ideal subjects for investigation by concise methods.

Stomach analyses.

A total of 39 stomachs was examined, seven proving empty. The results are not truly indicative of the relative amounts of different food types, since in a number of cases the birds were not taken at random, but definitely selected with a view to discovering variations of feeding habit in fresh places. The fulmars in the bird zone were not heavily sampled, results obtained early in the season showing that the predominant food, as in the case of the kittiwakes, was *Thysanoessa.* In consequence the importance of *Thysanoessa* is probably underestimated in the results given below. It is interesting to compare our general results with Hagerup's (**5**) investigation of 50 Greenland specimens (1924–5).

Thysanoessa inermis.

Twenty-three records, eight of large numbers. The results show, without doubt, that the occurrence of *Thysanoessa* in the extreme surface layer is not confined to the bird zone. On four occasions birds from packs feeding in various parts of Adolf Bay at a considerable distance from the glacier were found to have *Thysanoessa* in the gullet: and on a further occasion fulmars were noted in company with kittiwakes which were found to be eating *Thysanoessa.* It is interesting to note that the four positive records were all obtained before 20 August, i.e. some time before activity in the bird zone began to decline.

Thysanoessa has previously been regarded as a deep water form, very susceptible to light-shock (see Part 1 of the present paper). That its penetration to the extreme surface layer (except in water adjacent to ice) is only spasmodic

is suggested by its absence in any normal tow-netting, and the irregularity of the occurrence of casual packs of feeding fulmars.

The effect of ice on the distribution of *Thysanoessa* was found to be much more general than had been at first suggested by a study of kittiwake feeding localities. Fulmars were often noticed feeding at odd points along the glacier face, though only once in appreciable numbers (see also glaucous gull), on 15 August (see 1 (*e*)). They were also noted feeding in the neighbourhood of the larger icebergs, specimens containing freshly caught *Thysanoessa* being obtained on three occasions. The number of birds involved was never large, and in this respect both these types of feeding are relatively unimportant. They do, however, throw some light on the problem of *Thysanoessa's* swarming, showing that a lowering of salinity and temperature rather than an increase of turbidity, with consequent decrease in light intensity, are the primary factors concerned.

Thysanoessa is possibly the "large *Mysis*" of Van Oordt 1921 (**18**). He records fulmars at Cape Boheman full of a "large *Mysis*" mainly recognized by its eyes. The birds came mainly from the Ebba Valley direction.

Mysis oculata.

A single record, from a fulmar feeding in Bay 1, near the shore. It was unusual to find fulmars feeding in the inshore zone except in this particular bay, which often contained offal from the Bruce City camp.

Pseudalibrotus littoralis.

Three records, all from birds coming from the glacier. This Amphipod appears to be of causal occurrence and minor importance in the surface layer.

Euthemisto libellula.

Five records. One bird containing a large number of fresh *Euthemisto*, as well as *Thysanoessa*, was obtained in the neighbourhood of a large berg stranded near the boulders, which is interesting in connexion with the Wijde Bay observations (see 1 (*f*)).

Sagitta elegans arctica Ritter-Zahony.

Although a regular and plentiful feature of the plankton, this Chaetognath did not figure at all prominently as a general article of diet. Four records were obtained, all in late July, from packs feeding actively; but in each case partly digested *Thysanoessa* were found in the stomach, suggesting that the birds in question had come from the bird zone. The fulmar was the only species in which *Sagitta*-eating was observed, and in its case it appeared to be indulged in only as a last resort.

Cyanea capillata.

Four records. This jellyfish was relatively common, and seems to have occupied a position similar to that of *Sagitta* in fulmar diet.

Hyperoche Kröyeri Bovallius.

This is a small Amphipod parasitic on *Cyanea*. It was found in one of the stomachs, having presumably been eaten together with its host.

Cephalopods.

The beaks of small Cephalopods were obtained on a number of occasions, but as no other portions of the animal were ever identified, and as no Cephalopods were observed in the district it is probable that this food had been taken elsewhere. In Greenland Hagerup found Cephalopod beaks in all the specimens he examined.

Fish.

Four records. All remains obtained were too far digested to be identifiable. As in the case of kittiwake, fish were an inconspicuous item of diet. Hagerup gives 6% as the figure in Greenland.

Offal, etc.

Fulmars were inveterate scavengers and fed readily on camp offal dumped in the sea. Apart from this abnormal source, the supply of offal was not extensive and in consequence of their limited mobility on land they were not able to scavenge at the foot of bird cliffs after the manner of the glaucous gull. They were almost omnivorous. Green vegetable matter and bunches of their own feathers were also found on a number of occasions. (Hagerup recorded 2% of leaves.) Van Oordt (**18**) records fulmars feeding on garbage at Cape Boheman and Le Roi (**10**) on whale carrion. Longstaff (**11**) observed them eating seal carcases, and diving after the sinking meat; we found this also at Bruce City. Hagerup states that they eat offal "only by chance". It seems probable that this is true.

Though Hagerup records fulmars eating pelagic snails, ctenophores such as *Beröe*, and Annelids, we found no records of these, though such food was relatively abundant in the district.

Hagerup's description of the fulmar as a "plankton bird" was based on his discovery in 100% of the birds he examined of red oil derived from Crustacea. This raises an interesting point. R. Fabre & E. Lederer (**3**) showed in 1933 that the pigment responsible for the reddish colour of the zooplankton oils is astacin. They have suggested that in whales it is used possibly to produce, indirectly, supplies of vitamin A. This indicates a line of investigation of the red oil in the fulmar and other birds.

This pigment may possibly be responsible for the colour of the false "red snow" recorded as early as 1861 by J. Lamont (**8**), and in 1921 by Summerhayes & Elton (**16**). Both these authorities have suggested that this is the droppings of little auks or other plankton feeders, and Summerhayes & Elton actually found, in Bear Island, that some "red snow" consisted of the remains of Crustacea.

(*h*) *Arctic tern*

Terns were well established as a nesting species in the area, but compared with fulmars their numbers were small, the population of the two colonies in the Bruce City district not exceeding 150 birds. The results given below are given chiefly from birds taken while feeding in the inshore zone, and do not give a direct indication of the relative consumption of various foods.

Thysanoessa inermis.

Eight records. This was actually the most important item of diet, upwards of 50 terns feeding regularly in the brown zone outside the limits of the kittiwake pack during July and the first part of August. These birds were not extensively sampled, when once it had been established that the food taken was *Thysanoessa*. The casual capture of *Thysanoessa* was noted from several points in the middle of Adolf Bay, from the zone along the outside of the boulders, and from the surf in Bay 1: corroborative evidence was thus provided of the general distribution in the surface layer.

Mysis oculata.

Three records. *Mysis* was extremely plentiful in the inshore zone and boulder region but the vast majority of individuals belonged to a recent brood and were small in size. Terns only appeared to take the much larger and rarer individuals of the previous brood: hence *Mysis* does not figure as prominently as might be expected in tern diet. Summerhayes & Elton (**16**) record it from exactly the same place in 1921, while Montague (**13**) records terns feeding on "Mysids" in the deep waters of the fjords.

Pseudalibrotus littoralis.

A single record, from a bird fishing off the point of the south-west moraine on 16 July. This is in accordance with the fulmar results.

Gammarus locusta zaddachi.

This Amphipod occurred plentifully in the inshore zone, particularly in the neighbourhood of the boulders. It was normally found on the bottom in shallow water, among the weeds and stones. Terns could be seen any day searching for it in the pools of the boulders area, but it appeared to be somewhat elusive and did not ultimately form a large part of the food supply. The four records obtained were all from the extreme inshore zone, at the point of the south-west lateral moraine. *Gammarus*, by virtue of its habits, is clearly not available except for the more efficient species of surface feeders. Montague, and Summerhayes & Elton record *Gammarus locusta*, the latter from Pond 1 at Bruce City (**16**), though never in the boulder zone. Van Oordt also records it from Cape Boheman.

Lepidurus arcticus Pallas.

Terns were often seen fishing over Ponds 5 and 7 (**16**), as was recorded by Summerhayes & Elton in 1921: from examination of one bird shot there we agree with them that they took *Lepidurus*, which was abundant in the ponds. Montague also records terns eating *Lepidurus* in August.

Fish.

Four records.

Offal.

We never saw terns feeding on refuse, though Nicholson (**15**) records feeding on fish refuse in Godthaab (Greenland), and points out that this contradicts the "live food" theory.

(*i*) *Glaucous gull*

Though the glaucous gull fills the niche in Spitsbergen which is filled further south by the greater black-backed gull, namely, part predator and part scavenger, yet we find some justification for including it among the surface feeders. Out of three adults shot coming from the glacier face, two contained *Thysanoessa*. One of these also contained feathers, while the third contained digested offal. Glaucous gulls were always to be seen in small numbers at the glacier face, where besides feeding directly on plankton some distance from the bird zone, they were seen to feed, on several occasions, on the kittiwakes and fulmars which were killed or injured by the occasional falls of ice in the zone.

In late August and early September small numbers of young glaucous gulls were seen several times actually feeding in the bird zone with the kittiwakes. Adults were never seen to do this, but still fed in small groups under the cliff some distance away. Though we were unable to tow-net in these places we concluded from their way of feeding that *Thysanoessa* was probably their food.

Normally glaucous gulls were found everywhere along the coast. The remains of seals and food which were dumped in the sea by Bruce City often attracted as many as 30 birds. In September about 30% were young. Near Gips Hook we found them breeding in close association with auk colonies, as has generally been observed before (e.g. Bertram & Lack (**2**) on Bear Island).

At Advent Bay they took the place of the herring-gull and fed in the mud on the shore.

(*j*) *Ivory gull*

This was an irregular visitor to Bruce City and we met with it occasionally as a scavenger by the huts, or more often in the bird zone, feeding with the kittiwakes. Here we found sometimes as many as five, although the nearest known breeding place was Treurenberg Bay. One shot in the bird zone was full of *Thysanoessa*.

In the bird zone they were obviously reluctant to enter the water and were less efficient feeders than kittiwakes or fulmars. They spent most of their time sitting on small ice-floes with only occasional excursions into the zone. Longstaff (**11**), Montague (**13**), and Summerhayes & Elton (**17**) all mention this reluctance to enter the water, and Elton (quoted by Longstaff) suggests that their arctic winter habitat forbids the risk of a wetting with the consequent disaster of becoming temporarily helpless by the freezing of their plumage.

One gull was observed at Bruce City feeding on the remains of a kittiwake, and in Wijde Bay they fed on seal blubber and scraps left by the coastal survey party. On the ice-cap, 20 30 miles inland, ivory gulls followed the sledge parties as scavengers. Their scavenging habit is too well known to require confirmation from other sources.

(*k*) *Arctic skua*

Included here since it parasitizes the surface feeders, notably the kittiwake. The unfortunate kittiwakes had to run a gauntlet of three pairs of skuas on their flight line from the glacier to Gips Hook. Skuas were also seen sitting on floes in the open bay and attacking kittiwakes from the bird zone, and one actually appeared once chasing them in the zone itself. They were never seen to attack the arctic terns in their breeding grounds, in fact the opposite was the case if either of the Bruce City pair ventured too near the ternery. Near the glacier, however, terns were successfully victimized. Van Oordt (**18**) records one actually wounding and killing a purple sandpiper on the wing, though we never saw one so much as approach any of the numerous local purple sandpipers.

In Greenland Longstaff (**12**) has found flowers, moss, leaves, etc. in their stomachs and we can substantiate this from a record of a young one at Bruce City which contained a few plant shoots, some pebbles and mosquito remains.

4. Food supply, part 2: divers

The population of divers in the Adolf Bay area was considerably smaller than that of the surface feeders. Travelling censuses by boat in various directions across the bay for a total of 36 miles between 21 July and 5 August (the date on which the little auks began to depart), gave the following mean densities per square mile:

Brünnich's guillemot ...	9
Mandt's guillemot	15
Little auk	44
Spitsbergen puffin	12

On 21 August a census along the 7 miles of coast between the glacier and Cape Ekholm gave a total of 79 adult and young eiders. These always fed in the inshore region, and the figure then probably represents accurately the total population of that area.

This relative scarcity of divers in the district is partly due to the lack of suitable breeding cliffs (except possibly in the case of Mandt's guillemot). It may also be taken as an indication of the scarcity of available food, even for the more efficient feeders.

(*a*) *Seals.*

Seals present in the Adolf Bay district were the Inner Fjord seal, *Phoca hispida*, and the bearded seal, *Erignathus barbatus*, as a very occasional visitor. We shot eight seals (*hispida*) in or near the bird zone. Every one contained *Thysanoessa*, the largest stomach content being 5000. Three stomachs contained *Euthemisto* in some numbers as well. Another, shot near Cape Rudmose, contained two fish, *Boreogadus saida* Lepech, the arctic cod. This was the only time fish was found in a seal. Seals were abundant throughout July and August, but fell off rapidly in number at the beginning of September. It was usually possible to count 40 or 50 in a day within 400 yards of the glacier, and there were often as many as six swimming in the bird zone at one time. Lamont (**9**) records an example of *Phoca hispida* as "full of red prawns".

(*b*) *Northern eider*

In 1924 Montague (**13**, **14**) found that the northern eider lived almost entirely on molluscs, with some vegetable food (e.g. grazing on *Glycera vilfoidea*). He also recorded an Annelid eaten in the littoral region.

Of the 10 specimens we examined with food in the stomach Crustacea appeared in seven, molluscs in four, fish in one and Annelids in one. The distribution was as follows:

Crustacea:
- *Mysis* in two.
- *Gammarus* in four.
- *Hyas araneus* L. (Spider-crab) in two.
- *Eupagurus pubescens* Kroyer (Hermit-crab) in one.
- *Pseudalibrotus littoralis* Kroyer (Amphipod) in one.
- *Anonyx nugax* Phipps (Amphipod) in one.
- *Spirontocaris gaimardii* in one.

Mollusca:
- Cephalopod "beaks" in one.
- Lamellibranchs in three.
- Gastropods in one.

Annelids:
- Remains in one.

Fish:
- Vertebrae in one.

Eider were found feeding in the numerous small bays along the coast, and seldom appeared in mid-bay, though in July male flocks were observed in Klaas Billen Bay resting on the open water. Their inshore feeding habits were probably responsible for their being the only species from which *Thysanoessa* was not recorded.

(c) *Brünnich's guillemot*

Montague (**13**) recorded that this bird fed entirely on fish. In the Klaas Billen Bay district we found that this was not the case in the four specimens which we examined. All of these contained *Thysanoessa* in numbers, and two contained also a species of prawn, *Spirontocaris gaimardii*. Fish were absent. Throughout July Brünnich's guillemot was encountered feeding in deep water in Klaas Billen Bay, or in the middle of Adolf Bay. After the beginning of August, however, it disappeared altogether from the north of Klaas Billen Bay and we only met it again off Gips Hook on our way home.

(d) *Mandt's guillemot*

Montague (**13**) gives fish as its principal food, and records also the pteropod *Clio*. Van Oordt (**18**), however, records Crustacea and molluscs from Cape Boheman.

Of the 21 positive specimens which we examined we found:

Fish:
In seven, including *Leptoclinus maculatus* Fries, the butter-fish (three times probably).

Crustacea:
Thysanoessa in six.
Euthemisto in four.
Mysis in five.
Gammarus in one.
Spirontocaris gaimardii in three.
Sclerocrangon boreas Kroyer in one.
Hyas araneus in one.
Eupagurus pubescens in one.

Molluscs:
Gastropods in five.
Lamellibrach in one.

Annelids:
Harmothöe imbricata in one.
Vegetable matter in one.

Mandt's guillemot was generally restricted to the inshore region and was often noticed near icebergs. It fed closer to the glacier than any other auk. Young mandt's appeared first in the first week in August, and in early August it was possible to count from 20 to 50 birds feeding in Adolf Bay. Later the numbers decreased, until in September only a few young were left.

(e) *Little auk*

Owing to their unexpected departure from the Adolf Bay region we were unable to get more than three positive specimens of little auks' stomachs, taken about $\frac{3}{4}$ of a mile from shore. Montague (**13**) gives principally *Mysis* in the deep water of the bay; two of our specimens contained *Thysanoessa*, and

one *Euthemisto*. No fish were found. On the travelling censuses we took by boat in Adolf Bay we found the little auk to be the most numerous of its tribe during July. We once counted 86 between the Nordenskiold glacier and Bruce City, and the average was about 40, confined to the deeper parts of the bay. At the beginning of August the numbers suddenly decreased and we did not see one after 6 August.

(*f*) *Spitsbergen puffin*

This was the most regular auk in the area except for Mandt's guillemot, and although it diminished considerably in numbers at the beginning of August it never entirely disappeared. It fed both in the inshore region and in the deep waters of the bay.

Of the 10 specimens we examined we found:

Crustacea:
Thysanoessa in ten.
Euthemisto in three.
Mysis in two.

Fish:
Remains in seven, including *Boreogadus* and possibly *Leptoclinus*.

5. Addendum: the purple sandpiper

With the exception of the snow-bunting, which was present in fair numbers round Bruce City, this was the only land bird that bred and fed regularly in the district; it fed both on the land proper and in the intertidal zone, and it was in the latter that it played a small part in the local marine ecology. Three pairs bred round the Bruce City ponds and one in Bay 1.

Of the 10 stomachs examined we found:

Crustacea: *Gammarus* in four. (Shot feeding at various times at the boulders, at low water, where a flock of as many as 49 was seen on 29 July.)

Insects: The remains of what were probably Collembola were found in one out of two shot on the shingle above the high-water mark.

Vegetable remains were found in the other.

Four stomachs were empty except for small pebbles.

The diet of the purple sandpiper can be best judged from the writings of various authorities. Le Roi (**10**) said it ate chiefly vegetable matter during the breeding season, and later ate "sea-animals near the shore". At Bruce City in 1921 Summerhayes & Elton (**16**) found it eating *Lepidurus* from the ponds in two cases and Hymenoptera in one. The same writers (**17**) say that the common littoral red mite *Bdella littoralis* L. is probably distasteful to it. In North East Land they recorded (**17**) the Collembolan, *Achorutes viaticus* Tullb. and the Annelid *Lumbricillus aegialites*, which was also recorded by Montague (**13**).

In Bear Island in 1921 Summerhayes & Elton (**16**) found Collembola and flies eaten, and in 1932 Bertram & Lack (**2**) found there that purple sandpipers

caught Chironomid fly larvae through cracks in the ice on frozen lakes. In Greenland Longstaff (**12**) records molluscs, all manner of insects, a few Annelids, and a few seeds. The truth of Elton's remark that "it eats what it can get" seems now self-evident. An important fact is that owing to its diet of plants and both terrestrial and marine invertebrates it plays a part in more than one ecological zone.

Summary of food of birds investigtaed

	Kittiwake	Fulmar	Arctic tern	Glaucous gull	Ivory gull	Arctic skua	Seal	Northern eider	Brünnich's guillemot	Mandt's guillemot	Little auk	Spitsbergen puffin	Purple sandpiper
CRUSTACEA:													
Spirontocaris gaimardii	.	.	.	.	.	.	*	*	**	*	.	.	.
Sclerocrangon boreas	.	.	.	.	.	.	.	.	.	*	.	.	.
Thysanoessa inermis	***	***	***	**	**	***	***	.	***	**	**	***	.
Mysis oculata	*	*	**	.	.	.	*	*	.	**	.	*	.
Euthemisto libellula	**	*	*	*	.	*	**	.	.	*	*	*	.
Pseudalibrotus littoralis	.	*	*	.	.	.	.	*	.	.	.	.	.
Hyperoche krŏyeri	.	*	.	.	.	.	.	.	.	.	.	.	.
Gammarus locusta zaddachi	.	.	*	.	.	.	*	**	.	*	.	.	**
Anonyx nugax	.	.	.	.	.	.	.	*	.	.	.	.	.
Hyas araneus	.	.	.	.	.	.	.	*	.	*	.	.	.
Eupagurus pubescens	.	.	.	.	.	.	.	*	.	*	.	.	.
CHAETOGNATHA:													
Sagitta elegans arctica	.	*	.	.	.	.	.	.	.	.	.	.	.
COELENTERATA:													
Cyanea capillata	.	*	.	.	.	.	.	.	.	.	.	.	.
ANNELIDA:													
Harmothŏe imbricata	*	.	.	.	.	.	.	.	.	*	.	.	.
Unidentified	.	.	.	.	.	.	.	*	.	.	.	.	.
MOLLUSCA:													
Lamellibranch sp.	.	.	.	.	.	.	.	**	.	*	.	.	.
Gasteropod sp.	.	.	.	.	.	.	.	*	.	**	.	.	.
Cephalopod sp.	.	*	.	.	.	.	.	*	.	.	.	.	.
FISH:													
Leptoclinus maculatus	.	.	.	.	.	.	.	.	.	*	.	*	.
Boreogadus saida	.	.	.	.	.	.	*	.	.	.	.	*	.
Unidentified	*	*	*	.	.	.	.	*	.	*	.	**	.
OTHER FOODS:													
Offal	.	**	.	**	**	.	.	.	.	.	.	.	.
Vegetable matter	*	*	.	.	.	.	.	.	.	*	.	.	.
NON-MARINE FOOD:													
Lepidurus arcticus	.	.	*	.	.	.	.	.	.	.	.	.	.
Mosquitoes	.	.	.	.	.	*	.	.	.	.	.	.	.
Collembola	.	.	.	.	.	.	.	.	.	.	.	.	*

*** Very important. ** Relatively important. * Recorded.

6. ACKNOWLEDGEMENTS

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7. SUMMARY

1. A general account is given of the marine feeding population of Adolf Bay, part of the Inner Fjord zone of West Spitsbergen.

2. A localized flocking of surface feeding birds was observed at the face of the Nordenskjold glacier, and was studied qualitatively and quantitatively in detail. The glacier drainage system was found to be causing a surface swarming of the euphausid *Thysanoessa inermis*. The mean number removed per day by kittiwake alone from the zone was approximately 5,778,000.

3. A measure of correlation was obtained between bird numbers, air temperature and hydrographical observations.

4. The rarity of extra-zonal feeding records suggests that the effect of the glacier melt-water alone determines the presence of kittiwake in Adolf Bay.

5. Investigation of a glacier in Wijde Bay showed that this effect was not unique.

6. Examination of other surface feeders showed that *Thysanoessa* was the most important food in the district.

7. A survey of the distribution and food of diving birds was made. *Thysanoessa* was again found to be the most important food. The low density level suggested that food was not generally plentiful.

8. The details of the food-supply are summarized in a table.

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NUTRITION OF *GAMBUSIA AFFINIS* ON THE RICE FIELDS OF TURKESTAN

By N. P. SOKOLOV and M. A. CHVALIOVA

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(*With* 5 *Figures in the Text*)

Gambusia affinis, brought from America to Europe, is now widely used as an ecological agent for combating *Anopheles* larvae. *Gambusia* has become acclimatized in all the South European countries, Germany and Austria included, as well as in China, Japan and Siam. The first successful introduction of *Gambusia* from America to Europe took place in 1921 into Spain whence it was spread to different parts of Italy and thence all over South Europe.

Gambusia was brought in 1924 from Italy to the U.S.S.R. and became widespread all over the country: Transcaucasus, Daghestan, North Caucasus, Azof and Black Sea region, the South Ukraine, the Moscow district, Turkestan, etc. Experiments on acclimatization of *Gambusia* in Turkestan made a good start at the end of 1929. In the summer of 1935 we made an attempt to acclimatize them on the rice fields of Turkestan. In the present paper we record only a few matters dealing with nutrition.

The analysis of *Gambusia* food was done by the usual method in ichthyology of examining the stomach contents. *Gambusia* were collected from the rice fields in the morning (at 6–7 a.m.), afternoon (at 1 p.m.) and evening (at 8 p.m.) over a total period of 10–15 days between 9 June and 1 September. A total of 500 stomachs was collected. Out of this number 273 were analysed, 54 being from young fish.

The analysis showed that *Gambusia* mostly feeds on products of animal origin. Only in 30 of the 219 adult stomachs analysed were remnants of vegetable food found—13·7% of the total. In young fish the percentage was 12·9 vegetable.

The food included the following animals: Mollusca, Crustacea (Copepoda, Cladocera), Acarina, Insects (Rhynchota or Hemiptera, Coleoptera larvae, Ephemeridae larvae, Trichoptera larvae, Chironomidae larvae, Culcidae larvae, *Anopheles* larvae), Rotatoria. And the following plants: Chlorophaeaceae, Desmidaceae. All these were present in the adults (male and female) and young examined, except that Mollusca did not occur in the females and young, and Trichoptera not in the females. These exceptions may have been accidental. We did not find any stomachs with exclusively vegetable food remains.

Table 1. *Food of* Gambusia affinis

(Percentage of stomachs containing different organisms)

Food	Adults	Young
Animal:		
Mollusca	2·3	—
Copepoda	4·1	9·0
Cladocera	10·0	40·6
Acarina	8·7	22·2
Rhynchota (Hemiptera)	21·5	—
Coleoptera larvae	16·9	42·6
Ephemeridae larvae	21·9	16·6
Trichoptera larvae	3·6	1·8
Chironomidae larvae	16·9	18·5
Rotatoria	8·7	40·7
Culex communis larvae	20·0	—
Anopheles	**32·8**	**64·8**
Plant	13·7	12·9

The following diagram shows the relative importance of different organisms in the food of *Gambusia* as regards quantity.

Figs. 1 and 2 show that *Anopheles* larvae play a dominant role in the food of *Gambusia* since they form 32·8 and 64·8% of the total food of adults and

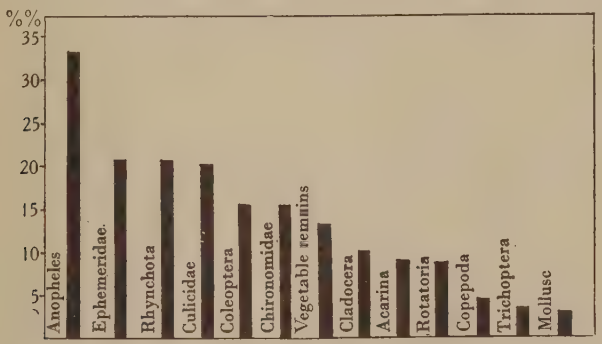

Fig. 1. Percentage of adult *Gambusia* stomachs containing different kinds of organisms.

young respectively. Some individual stomachs of adults, as well as of young ones, contained only *Anopheles* larvae (2–12 in number).

Although the method of recording the stomach contents is widely used in ichthyology, it has, however, proved insufficient to show the entire process of nutrition in fishes. Little attention seems to be paid to the questions of physiology and digestion in fish, whereas the study of these questions forms a cardinal basis for a detailed elucidation of the problem of fish nutrition.

The intensity of digestion in *Gambusia*, and particularly of the digestion of *Anopheles* larvae which form the bulk of the food, was studied in some preliminary experiments in an aquarium. The method of testing was as follows: a *Gambusia* was placed in an aquarium at a definite temperature; 5–10 *Anopheles* larvae were put into the aquarium; the time of swallowing of the

larvae by *Gambusia* was noted and afterwards the *Gambusia* was transferred for a certain time (30 min., 1, 2, 3 hours, etc.) into water of the same temperature, but without larvae; later, the *Gambusia* was dissected in order to find out to what extent the food had been digested. A total of 37 experiments was performed. The results demonstrate that at a temperature of 30° C. the process of digestion begins about 2 hours after the larvae are swallowed. A complete discharge of the stomach takes place in 3–4 hours, except for the chitinous parts which remain in it longer. Temperatures of 17–23° C. cause a slowing-down of digestion; but even at those temperatures the discharge of the stomach occurs 5–6 hours after the larvae are swallowed.

In order to compare the intensity of digestion we fed *Gambusia* on living *Daphnia*. In this case at a temperature of 30° C. digestion also set in approximately in 2 hours. A discharge of the stomach took place in 3 hours. Thus

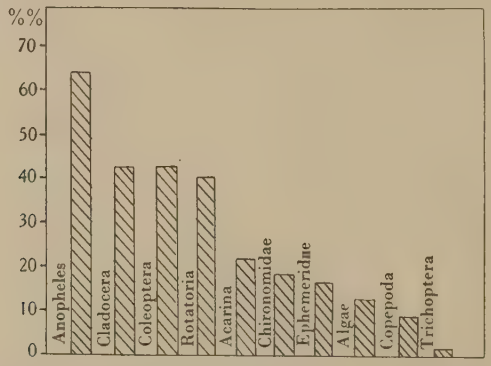

Fig. 2. Percentage of young *Gambusia* stomachs containing different kinds or organisms.

we did not detect any wide difference between digestion of *Anopheles* larvae and of *Daphnia*. There is an urgent need for physiological studies in order to obtain further evidence on the rate of digestion, as this subject is closely connected with *Gambusia* nutrition under natural conditions: especially for revealing the exact quantity of food eaten by *Gambusia* in a given time. If we compare the data just recorded with those obtained for other species, a rather high digestion rate of *Gambusia* may be noted. The highest digestion rate of bullheads and cod fed on *Gammarus* fell in the first 2 days, whereas in plaice also fed on *Gammarus* the stomach discharge took place in 24–36 hours.

It is evident that to a certain extent the digestion rate depends on the rate at which the stomach fills, as well as on the morphological structure of the intestine and on other systematic and biological peculiarities. Now let us consider the rate at which *Gambusia* swallows larvae. We studied the question of swallowing rates in connexion with digestion rates, as those two phenomena are closely connected and it is almost impossible to record them

separately. The rate of swallowing of *Anopheles* larvae by adult *Gambusia* is shown in Fig. 3. The average size of the *Gambusia* tested was 26·2 mm. The temperature varied from 18° to 21° C.

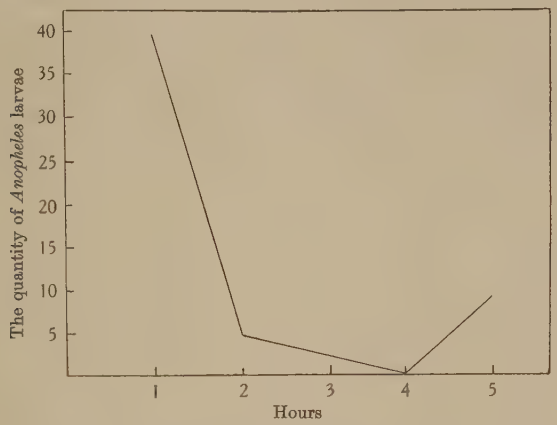

Fig. 3. Number of *Anopheles* larvae swallowed per hour, showing cycle of digestion (one adult *Gambusia*).

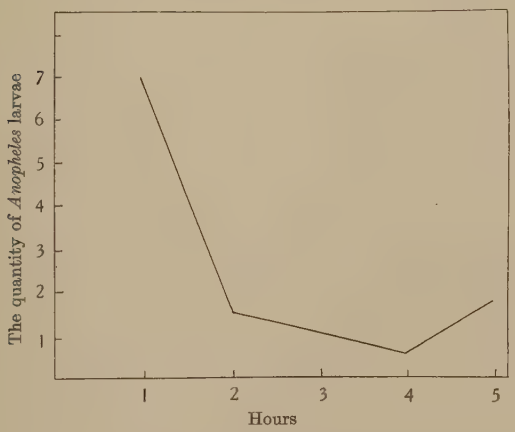

Fig. 4. Number of *Anopheles* larvae swallowed per hour, showing cycle of digestion (young *Gambusia*).

The above data on swallowing in the main confirm the observations herein recorded on the digestion rate. A sharp rise of the curve shows that the swallowing of larvae coincides with the fifth hour, when the effective digestion is in the main already over. Usually, if there is some food material, fishes do

not wait for a complete discharge of the stomach, but take the food much earlier according to the initial and present filling of the stomach and the kind of food. Swallowing continues also during the second and third hour, but its intensity falls, depending upon the rate of the stomach filling according to which the character of the curve may change. We may observe approximately the same curve of swallowing *Anopheles* larvae in young fish measuring 8–9 mm. at the same temperature. In this case as well as in the first one the rise of swallowing-rate coincides with the fifth hour after the initial filling of the stomach.

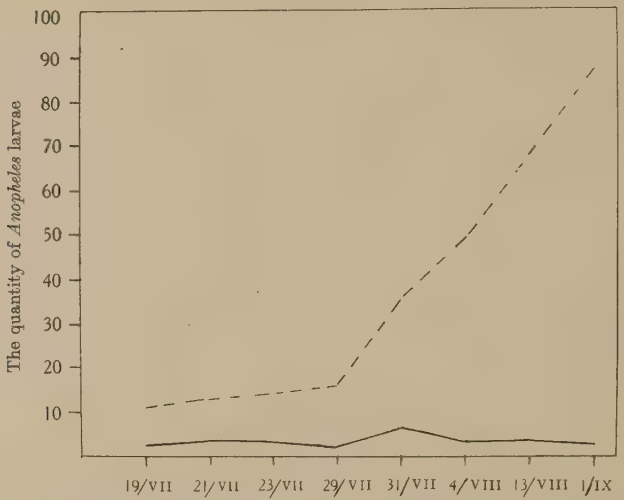

Fig. 5. Density of *Anopheles* larvae per sq. m. on experimental (with *Gambusia*) and control fields. Experimental ——; Control – – – –.

Thus the recorded data show us a high rate of digestion and consequently a rich food supply is necessary for a normal growth of *Gambusia* under natural conditions. The rice fields yield all the required conditions for a successful acclimatization of *Gambusia*.

We failed to achieve complete extermination of *Anopheles* larvae at a density of 2·3 *Gambusiae* per sq. m.; but nevertheless we can record a rather high effectiveness of extermination. Fig. 5 shows graphically the relation between the number of *Anopheles* larvae on rice fields where *Gambusia* was introduced and those obtained on the adjoining rice field where there were none.

The above graph shows an extremely small variation in the numbers of *Anopheles* larvae on the rice fields with *Gambusia*. The average density throughout all the experiments was 3·6 larvae per sq. m. with variations from 1·7 to 5·2 between July 19 and 31. After this the density fell again to 3·0 and did not

rise during the next period from August 4 to September 1. If we now compare these data with those obtained on the adjoining rice field without *Gambusia* it may be seen that the average extermination of *Anopheles* larvae extends to 93·1 % at some decades showing variations between 83·8–96·7 %. Assuming that other conditions are the same on both areas, these experiments clearly indicate the important role *Gambusia* plays as a new ecological method of combating the *Anopheles* larvae on the rice fields.

The density of *Anopheles* larvae varies on different rice fields, being quite small on some of them. In such cases *Gambusia* may be regarded as a sufficient agent of repression with the *Anopheles* larvae, without applying any other methods.

Summary

1. *Anopheles* larvae play an important role in the food of adult *Gambusia* on the rice fields, amounting to 32·8%; Ephemeridae, 21·9%; Rhynchota, 21·5%.

2. *Anopheles* larvae form the bulk of the food of the young fish, amounting to 64·8%.

3. *Gambusia affinis* exterminates the *Anopheles* larvae to about 80–90%. This shows the important role *Gambusia* plays in the ecological method for combating *Anopheles* larvae on the rice fields.

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NOTES

FLUCTUATIONS IN NUMBERS OF CRAYFISH

In a previous paper (1933, *J. Anim. Ecol.* 2: 184) the author drew attention to the fluctuations which occur in the numbers of the freshwater crayfish, *Potamobius pallipes* Leréboullet. Below is given, in note form, the present status of crayfish in rivers of the Oxford district.

The Ock. Crayfish disappeared about 1928 and although I have been told that a few crayfish have recently reappeared, I have been unable to discover them after careful search and conclude that they are either absent or very scarce.

The Thame. In 1934 and for at least six years previously crayfish were abundant and a fisherman with a dozen nets might take a sackful in an evening. In the autumn of 1935 they were scarce; during August (1935) two fishermen with 7 nets each had caught 17 crayfish after over 4 hours' fishing. The crayfish that survive are large.

The Windrush. Crayfish are at present (1935) abundant in the neighbourhood of Burford and down stream to beyond Minster Lovell. As they were abundant in 1931 and probably before, a decrease may be anticipated soon.

The Glyne and Dorne. In 1900 these rivers contained crayfish, although an epidemic at that time had depleted the Evenlode and Thames. The Glyne and Dorne flow through Blenheim Lake (an area of 119 acres of deep water) before reaching the Evenlode, and the lake seems to have acted as a barrier. It appears that late last century some crayfish (species not stated) were introduced into the Thames with a view to establishing a larger breed. It was subsequent to this that the epidemic occurred. (Information from the Rev. J. R. Marriott, Wootton, Oxfordshire.)

The Evenlode. Crayfish were abundant at the end of last century but disappeared about 1900. Until 1918 none were recorded, but at that date some were introduced. Now (1935) they are abundant.

Recently a comprehensive paper has appeared on the etiology of crayfish disease on the continent:

Schäperclaus, W. (1935). "Die Ursache der pestartigen Krebssterben." Zeitschrift für Fischerei, 33: 343.

J. E. DUFFIELD

A METHOD OF COUNTING LARGE SAMPLES OF SMALL ARTHROPODS

Various methods have been described for the extraction of small Arthropods (Collembola, mites, thrips, etc.) from soil, vegetation or refuse, in which the animals are finally floated on the surface of water and may be, subsequently, trapped on a filter paper. In a single sample of this nature over a thousand specimens, comprising many species, may be obtained, and unless mechanical

aids are utilized in studying the filter paper there is grave danger that many individuals will remain unnoticed. To ensure accuracy in this respect the writer has devised the following technique.

The water and floating animals are decanted into a funnel containing a filter paper, folded in four, which has previously been ruled with pencil into 3 mm. squares. The sunken debris is not poured in, but is washed twice and the surface water again filtered through the same paper. The residue, which may contain a few larvae, nematodes, etc., is retained for separate examination. When filtering is completed, the paper is unfolded and placed under a Petri dish, inside which has been attached, by a ring of plasticine, a pad of cotton-wool soaked in ether. Care is taken to ensure that this pad does not touch the filter paper when the dish covers it. After about 10 min. all the organisms should be dead, although some mites may require longer exposure.

The unused half of the filter paper is then cut off and the half carrying the organisms placed on a sheet of glass and examined square by square under a dissecting binocular. (A magnification of 25 diameters is satisfactory, but, in any case, the squaring of the filter paper should be such that one square is contained in the field of the microscope.) The organisms on each square are then picked off with the point of a needle and are counted, sorted into species and appropriately preserved in one operation. Should it be necessary to discontinue the examination for any length of time, the filter paper should be covered to prevent undue evaporation.

The advantages of this method are:

1. No organism need be overlooked, as many are certain to be if searching is random.

2. The sample can be sorted into species at once; this is not possible without the use of a microscope and if the organisms are first sorted into orders, a further chance of error is introduced.

3. There is ultimately a saving of time since sorting and counting are done in one instead of two operations.

Finally, it may be noted that when it is not necessary to preserve organisms, but merely to count them according to species, a sheet of glass, squared with a diamond, may be used over a plain filter paper.

JOHN FORD

(Hope Dept. of Zoology (Entomology), University Museum, Oxford)

REVIEWS

THE AUGUST ISSUE OF *THE JOURNAL OF ECOLOGY* (VOL. 24, NO. 2, AUGUST, 1936)

This number contains eight papers, a long letter and two or three reviews. The papers are very various and do not readily lend themselves to grouping. The concluding parts of the late Dr Mukerji's extensive work on dog's mercury contain a fairly thorough analysis of the relation of the plant to different soil factors. P. W. Richards concludes his account of Sarawak rain forests, N. Polunin summarizes the vegetation of Norwegian Lapland in the form of successional series and H. G. Vevers contributes a good description of the land vegetation of the lofty rocky islet, Ailsa Craig, in the Firth of Clyde. Violet Grubb gives a very thorough account of the relation of the seaweed communities of two small reefs on the Dorset coast to the exposure factor. Winifred Brenchley and Katherine Warington describe, with the aid of numerous tables of figures, the rate of re-establishment of different weeds on arable land that has been fallowed, and Mrs Maguinness summarizes a survey, already published in France, of narrowly localized colonies of thermophile species in Hérault, giving convincing reasons for regarding them as relicts of a Tertiary climate. W. Watson adds to his valuable series of general papers on the Bryophytes and Lichens of different types of British habitat an account of the distribution of these plants in woods other than beech-woods (dealt with in the previous issue).

C. Gillman, the geographer, vigorously attacks John Phillips' interpretation of the successional relations of dominant forest communities in Tanganyika Territory. Reviews include a notice of Stapledon's important book on the present and future of British land.

A. G. TANSLEY.

SEA FISH OF NORTHERN EUROPE

Ernst Ehrenbaum. *Naturgeschichte und Wirtschaftliche Bedeutung der Seefische Nordeuropas.* 337 pp., 276 figs. E. Schweizerbart'sche Verlagsbuchhandlung (Erwin Nägele), G.m.b.H., Stuttgart, 1936. Price RM. 35.25 (RM. 47 in Germany), bound.

This forms Vol. 2 of the well-known and useful *Handbuch der Seefischerei Nordeuropas*, which has been in course of publication for some years. Dr Ehrenbaum is of course one of our greatest authorities on fish, and he has the additional qualification of having taken part for many years in practical fishery research, enriching it with many valuable contributions. In this book he summarizes in a masterly way the main facts regarding the natural history of all species of fish inhabiting North European waters of moderate depth.

Special attention is given to the species of commercial importance, and the ecologist will here find, with respect to these, much information about distribution, migrations, feeding habits, spawning grounds and seasons, rate of growth, age at first maturity, fluctuations, and so on, which is otherwise difficult to find except by a prolonged search through fishery literature. The more important references are given for each group, thus facilitating further study. The illustrations are numerous and carefully selected, and the plates are excellent. Subjects of general interest, such as the "overfishing" problem, and the "race" question, are touched upon in connexion with the plaice and the herring.

In sum, a very valuable work of reference, indispensable to all workers on the ecology of marine fish.

E. S. RUSSELL.

A POPULATION EXPERIMENT WITH SALMON

R. E. Foerster. *An investigation of the life history and propagation of the sockeye salmon* (Oncorhynchus nerka) *at Cultus Lake, British Columbia. No. 5. The life history cycle of the* 1926 *year class with artificial propagation involving the liberation of free-swimming fry.* J. Biol. Can. 2: 311–33, 1936.

This work on the sockeye salmon was undertaken to determine whether artificial propagation would be a remedy for the decline of the salmon fisheries of the Pacific coast of North America. Cultus Lake, situated on a sub-tributary of the Fraser River, has many advantages for this investigation, the principal being that it is possible to trap and count all adult fish entering the lake to spawn and all young fish migrating seaward.

To obtain adequate controls the adults have been allowed to proceed to the lake to spawn naturally every other year, whilst in the alternate years the fish have been trapped, spawned artificially and the eggs obtained hatched in a hatchery, the young fish being liberated in the lake as fry. In all years all the adults and all the seaward migrants are counted and samples examined to determine their age and growth-rate. Since sockeyes may migrate to the sea as fry, yearlings or two-year-olds and return as three-, four-, or five-year olds, these data and their statistical analysis are the foundation of the work.

This paper gives the result of the artificial spawning of the run of 1926. In that year the number of fish arriving at Cultus Lake was 5071 of which 1949 were females. The total egg-production was estimated at 8,770,000; of these 13·4% were lost by the females dying before they could be stripped, 67·5% were successfully reared in the hatchery and liberated as fry in the spring of 1927, 3·9% migrated to the sea as one- or two-year olds and 0·09% returned as adults in the years 1929–31. As the loss of females by retention would not have occurred had they been allowed to spawn naturally in the lake, these figures are not strictly comparable with those obtained for the 1925 run; and throughout the paper percentages have also been calculated on the number of eggs available for stripping, but the difference is small and does not affect the proportion of adults returning.

The 0·09% of the total eggs that survived to return as adults represents 7785 fish so that it appears that the net result of the reproduction of 5071 fish in 1926 was an increase of 2714. This is, however, not a true measure of the "biotic potential" for, contrary to what was formerly believed, part of the Cultus Lake run arrives in the Fraser River when the commercial fisheries are operating.

Unfortunately the method of marking used has not proved satisfactory and no estimate of the proportion of fish taken by the nets can be made. The lack of figures for total productivity does not however affect the main problem, for the efficiency of artificial as against natural spawning can be judged from the number of downstream migrants. The whole investigation was well-planned and has been admirably carried out and there is little doubt that, when the time comes, a definite answer to the question will be given.

F. T. K. PENTELOW.

CLIMATE IN ECOLOGY: A NEW JOURNAL

Bioklimatische Beiblätter der Meteorologischen Zeitschrift. Edited by **Franz Linke** and **Wilhelm Schmidt.** Publisher: Freidr. Vieweg und Sohn Akt.-Ges., Braunschweig, Germany. Price 15 RM. per annum.

This new quarterly, running to about 200 large pages, is sponsored by the Deutschen Meteorologischen Gesellschaft and the Österreichischen Gesellschaft für Meteorologie, and is now (1936) in its third volume. It contains a number of original contributions, a certain number of general reviews of subjects, and a large number of abstracts of literature which are really more than abstracts since many of them are written from a useful critical standpoint.

As would be expected, the general standard of production and the scientific value of

most of the papers is high. Ecology is a complex of borderline subjects, and this journal covers in a very useful, though necessarily rather arbitrary, way the diffuse literature upon the relation of organisms to climate and weather conditions. Within these limits the net is thrown very wide, and covers not only plants and ordinary animals, but also man and bacteria (as studied in medical research investigations). Insect ecology occupies an important place in the abstracts. Ecologists not familiar with European literature will find all of them useful as a guide to current work.

The journal deserves support by ecologists, who can aid the editors by sending their publications for review: Prof. Dr Franz Linke, Feldbergstr. 47, Frankfurt a.M. Germany (human and animal ecology), or Prof. Dr Wilhelm Schmidt, Hohe Warte 38, Vienna 19, Austria (plant ecology)).

CHARLES ELTON.

TREES AND SHRUBS

F. K. Makins. *The identification of trees and shrubs.* Many text-figures. Pp. 1–311. Large octavo. Dent & Son, London. Price 15*s.*

THE subtitle is: "How to name without previous knowledge of botany any wild or garden tree or shrub likely to be met with in the British Isles, with 2500 diagrams made by the author." It explains the scope of this very useful book. The time is past when ecologists can pretend that the "indigenous" flora and fauna are the only worthy objects of their attention; while the introduction each year of a number of foreign animals is an important reason for including introduced plants in the ambit of ecological survey work.

CHARLES ELTON.

ANADROMOUS FISH

W. J. M. Menzies. *Sea trout and trout.* Pp. 1–230. London: Edward Arnold & Co., 1936. Price 10*s.* 6*d.*

THIS book is written by one who has acquaintance with his material both as a scientist and as an angler. A variety of aspects is treated that may be expected to have general appeal. In addition to a thorough treatment of the life-history of the sea trout the following are but a few of the topics dealt with: the possible evolution of the brown trout through the loss of the marine habit due to the heating-up of the sea; the great variety of forms, sizes and local races of sea trout (a consequence of the great plasticity of the species); methods, experiences and results of marking experiments; protective coloration; food, habitat, parasite and hatchery problems. The biologist will deplore the statement that "It is very seldom if ever that animals, existing in a state of nature...are liable to epidemic... diseases." He will regret that references to the work of the Fishery Board for Scotland are not given as specific papers in a full bibliography; also that through lack of sub-titles it is not always easy to sift out particular information from the narrative. Nevertheless the book gives a valuable account of present knowledge.

D. H. CHITTY.

TEXT-BOOK OF ANIMAL ECOLOGY

Charles Elton. *Animal Ecology.* Sidgwick & Jackson, 44 Museum Street, Ltd., London, W.C. 1, 1935. (Second impression with additional notes.) i–xxx, 1–209 pp. Price 10*s.* 6*d.*

THE problem of supplying text-books for a rapidly advancing department of science is an exceedingly difficult one. Since the first edition of Elton's *Animal Ecology* in 1927[1] it has remained the only book in English but one in its field, that of setting forth the essential

[1] Reviewed by A. G. Tansley (1928), *Journal of Ecology*, 16: 163–9.

principles and concepts of animal ecology for elementary students. The need for a second impression would seem to be an indication of its wide use. There are no essential changes from the first impression although a section on "Notes added to the Second Impression" is added at the beginning of the book. These are treated under divisions corresponding to the chapters of the text with the avowed purpose of supplementing them with brief comments on the literature of 1927–35.

The portion of the Appendix dealing with the monographs on taxonomic groups of insects has been revised and brought up to date by Dr B. M. Hobby. While perhaps the time has not yet come for a complete rewriting of the book, the supplementary preface has not covered the more recent work as thoroughly as the original work set out to do. While omission of certain aspects of more recent advances in world progress in both theory and actual survey detracts but little from the book as a text, a field still remains open for a detailed elementary text-book on field animal ecology.

J. RICHARD CARPENTER.

NOTICES OF PUBLICATIONS ON ANIMAL ECOLOGY

The entomological journals have been abstracted by H. F. Barnes and B. M. Hobby; the others by J. R. Carpenter, D. H. Chitty, Charles Elton and A. D. Middleton.

This series of notices covers most of the significant work dealing with the ecology of the British fauna published in British journals, large and small. Readers can aid the work greatly by sending reprints of papers and reports to the Editor, *Journal of Animal Ecology*, Bureau of Animal Population, University Museum, Oxford.

Copies of these abstracts, cut down to a width suitable for pasting on to five-inch index cards, are issued free with the *Journal*. They can also be obtained separately by non-subscribers, from the Cambridge University Press, Fetter Lane, E.C. 4, or through a bookseller, price 3*s*. 6*d*. per annum post free (about 250 notices, in two sets, May and November).

1. GENERAL PAPERS ON PARTICULAR ANIMALS

142. Berry, J. (1936). "An identification key to British grey geese." London Nat. for 1935: 90–6.

143. Killington, F. J. (1936). "A monograph of the British Neuroptera." Ray Society, London, 1: 1–269.

A complete account of the present state of knowledge of the British Neuroptera (*sensu stricto*) (lacewings) written both for the biologist and the systematist.

This volume includes general accounts of the early stages, a chapter on bionomics, and systematic studies of the Coniopterygidae, Osmylidae, Sisyridae and some of the Hemerobiidae.

144. Kimmins, D. E. (1936). "Synonymic notes on the genera *Chloroperia* [*sic*], *Isopteryx* and *Isoperla* (Plecoptera), with a list of the British species of *Chloroperla*." J. Soc. Brit. Ent. 1: 121–4.

Gives figures of structural characters used for the determination of the species of *Chloroperla* (stone flies).

145. Thompson, G. B. (1936). "A check list of the Hippoboscidae and Nycteribiidae parasitic on British birds and mammals." Ent. Mon. Mag. 72: 91–4.

146. Miles, H. W. (1936). "A revision of the British species of *Hoplocampa* Hartig. (Hymenoptera Symphyta)." Ent. Mon. Mag. 72: 58–62.

147. Diver, C. (1936). "A new genus of ants in Britain." Nature, 137: 458.

A member of the genus *Strongylognathus* was found in two places in south-east Dorset associated with *Tetramorium caespitum* as a slave-maker.

148. Fidler, J. H. (1936). "Some notes on the morphology of the immature stages of some British chafer beetles." Ann. Appl. Biol. 23: 114–32.

Contains a key for the rough identification of the most common genera.

149. Winckworth, R. (1933). "Names of British marine Mollusca, I." J. Conch. 19: 334–38: "Names of British Mollusca—II." *Ibid.* (1934), 20: 9–15; "Names of British Mollusca—III." *Ibid.* (1934), 20: 51–3.

A merciless revision of nomenclature.

150. Stephenson, T. A. (1935). "The British sea anemones." Vol. 2: 426 pp. Ray Society, London. Price 37*s.* 6*d.*

2. ECOLOGICAL SURVEYS AND HABITAT NOTES

(*a*) Marine and brackish

151. Lumby, J. R. (1935). "Salinity and temperature of the English Channel. Estimation of mean values for the upper water layer over the 25-year period 1903 to 1927." Ministry Agr. Fish., Fish. Invest. Ser. 2, 14, No. 3. (London: H.M. Stationery Office. Price 7*s.* 0*d.*)

Atlas of charts (15 × 21 in.) for each month and for the whole year.

152. Foxon, G. E. H. (1936). "Notes on the natural history of certain sand-dwelling Cumacea." Ann. Mag. Nat. Hist. 17: 377–93.

A discussion of the swimming, feeding, and breeding habits, the development of sexual characters, moulting, and collecting of three members of this group of Crustacea (*Pseudocuma longicorne, Iphinoë trispinosa* and *Lamprops fasciata*) at Glasgow.

153. Cooper, J. E. (1933). "The Mollusca of Chislet marshes." J. Conch. 19: 317–21.

A list of the molluscs found in the Chislet marshes which occupy the site of the old "Wantsum Sea", near Thanet.

154. Boycott, A. E. (1936). "*Neritina fluviatilis* in Orkney." J. Conch. 20: 199–200.

A note on this calcicolous species, with a map of its distribution in the British Isles.

155. Pelseneer, P. (1934). "Bionomics of a brackish-water nudibranch: *Limapontia depressa*." J. Conch. 20: 54–5.

A brief description of breeding habits and habitats. The more usually associated species, among the Mollusca, are: *Tellina balthica, Hydrobia ulvae, Alexia myosotis*, and often *Alderia modesta*.

156. Fisher, N. (1935). "Notes on the spawning of *Acanthodoris pilosa* (Abildgaard)." Proc. Malacol. Soc. London, 21: 249.

This nudibranch was studied in Ireland, living under stones among *Halichondria* and Ascidians on the shore. Spawn was laid in a ribbon on *Fucus*. Spawning occurs over a large part of the year in different places.

(*b*) Freshwater

See also **177**

157. Shrubsole, G. (1935). "Mollusca of the sheep ponds on the Eastbourne Downs." J. Conch. 20: 130–41.

Distribution of ten species of Mollusca (*Limnaea peregra, stagnalis*, and *truncata; Hydrobia jenkinsi; Planorbis alba* and *cristata; Sphaerium lacustre; Pisidium casertanum, milium*, and *nitidium*) in artificial sheep-ponds, mostly of cement construction, near Eastbourne.

158. Boycott, A. E. & Oldham, C. (1936). "A conchological reconnaissance of the limestone in West Sutherland and Ross." Scottish Nat. 47–52 and 65–71.

This study of certain limestone areas lying in non-calcareous country revealed several species not previously recorded from this part of Scotland, and some other species in much greater numbers than on surrounding areas. Lists are given, together with general habitat notes. *Limnaea involuta*, hitherto only known from Loch Crincaum in Kerry, Ireland, was found in a tarn near Inchnadamph.

159. Harrison, G. H. (1936). "Corixæ in Durham." Vasculum, 22: 33.

Corixa striata is the most abundant water-bug; most ponds produce no other species. Some ponds yield no *C. striata*, but only *C. geoffroyi*.

(*c*) Land

See also **179**

160. Robbins, R. W. & Parmenter, L. (1936). "Ecological section. Report for 1935." London Nat. for 1935: 12.

The London Natural History Society has started an Ecological Section. The first survey is on the flora and fauna of bracken (*Pteris*) in Richmond Park and Epsom Common.

161. Hughes, D. O. & Walters, W. G. D. (1935). "Soil survey of Wales. Progress report, 1931–34." Welsh J. Agric. 11: 188–208.

Summary of surveys in north-west Denbighshire, north-east Caernarvonshire, and Anglesey, with maps.

162. Sharp, W. O. (1935). "A soil survey in the valley of the Great Stour, Kent." J. S.-E. Agric. Coll. Wye, No. 36: 183–4.

Contains description and soil map for about 2 square miles, mostly on permanent pasture (partly under flood influence), with scattered woods.

163. Johnston, T. L. (1936). "Nesting habits of the willow-tit in Cumberland." British Birds, 29: 378–80.

Favourite nesting sites old birch woods with decaying stumps. Great tits and blue tits found to annex holes made by willow-tits.

164. Burr, M. (1936). "Scope for our Orthopterists." Ent. Rec. 48: 44–8.

A stimulating paper indicating the paucity of knowledge concerning the distribution of even the commonest British species and suggesting many lines of research.

165. Callan, E. McC. (1936). "A note on some Hymenoptera bred from a dead willow." J. Soc. Brit. Ent. 1: 128–9.

Wasps and their parasites.

166. Johnson, C. G. (1936). "The biology of *Leptobyrsa rhododendri* Horvath (Hemiptera, Tingitidae), the rhododendron lacebug. I. Introduction, bionomics and life history." Ann. Appl. Biol. 23: 342–68.

167. Marriner, T. F. (1936). "Some entomological Jacobites." Naturalist: 93–4.

List of insects living on or frequenting the ragwort (*Senecio jacobaea*).

168. Collin, J. E. (1936). "A note on Anthomyidae (Diptera) reared from the flowers of *Senecio*." Ent. Rec. 48: 53–4.

Distinguishes between *Pegohylemyia seneciella* and *P. jacobaeae*.

169. Pugh, C. H. Wallace (1936). "*Digonochaeta spinipennis* Mg. bred from thrush's nest." Ent. Mon. Mag. 72: 46.

Included in a list of eight Diptera reared from two nests.

170. Brown, J. M. (1936). "Yorkshire Psocoptera." Naturalist: 135–9.

List of 31 species found in Yorkshire, with some habitat notes.

171. Stringer, H. (1936). "Heterocera attacking *Cotoneaster horizontalis* and *microphylla*." Entomologist, 69: 144.

Includes in this country *Spilonota ocellana*, not hitherto recorded on this plant (*C. horizontalis*), *Eurhodope suavella* and *Ancylis achatana*.

172. Anon. (1936). "Micro-larvae mining in roots." Ent. Rec. 48: 9–10.

Very useful hints for breeders of Lepidoptera. See also 1936, *ibid.* 48: 20–1, 32–3, 48–9, 61–3, 74–5, 84–5.

173. Petherbridge, F. R. & Mellor, J. E. M. (1936). "Observations on the life history and control of the cabbage aphis, *Brevicoryne brassicae* L." Ann. Appl. Biol. 23: 329–41.

Includes list of host plants and natural enemies.

In 1934 the aphis overwintered only as eggs, but in 1935 probably both as viviparous females and eggs.

174. Austin, M. D. & Jary, S. G. (1934). "Investigations on the insect and allied pests of cultivated mushrooms. II and III." J. S.-E. Agric. Coll. Wye, No. 34: 70–86.

Part 2 describes the pests of mushrooms known in this country: 5 species of *Sciara* (Mycetophilid flies); *Aphiochaeta albidohalteris* (a Phorid fly); larvae of Cecidomyid flies; *Hypogastrura armata* (a springtail); several mites (*Caloglyphus kramerii* and others); and nematode worms which may cause a bacterial disease due to *Pseudomonas tolassi*.

Part 3 describes the whole fauna of the stable manure used for preparation of mushroom beds, based on samples (not quantitative) at Wye, Kent, in Oct.–Dec. 1933. About 30 species found, subdivided into those near surface and inside the manure piles (little difference is shown). Fauna mainly beetles and flies, with also a few mites, Collembola, woodlice and Dermaptera. Practically no trace of mushroom pest species was found in the manure.

175. Austin, M. D. & Jary, S. G. (1935). "Investigations on the insect and allied pests of cultivated mushrooms. IV and V." J. S.-E. Agric. Coll. Wye, No. 36: 103–110.

Continuation of work on fauna of manure used for mushroom cultivation. Lists are given of 23 species of insects for January-June and September to December, 1934, based on (not quantitative) sample counts. The species are noticeably different from those taken in 1933, and include some Sciarid fly pests. Mites were also found but not listed.

176. Miles, H. W. & Cohen, M. (1935). "The glasshouse Symphylid and its control." J. Minist. Agric. 42: 450–7.

This Myriopod (*Scutigerella immaculata*) has been found of late years in several glasshouses, where it injures lettuces, tomatoes and sweet peas. It is a soil insect, mainly living in the top 1 in. The optimum temperature is thought to be 50–60° F. Roots, especially of young plants, are damaged, and this paper describes methods of control.

177. Kevan, D. K. & Waterston, A. R. (1933). "*Vertigo lilljeborgi* (West.) in Great Britain (with additional Irish localities)." J. Conch. 19: 296–313.

A list of occurrences (38 places in Scotland, England and Ireland), lists of Mollusca and plants found associated with this species, and a discussion of its habitats. Chief mollusc associates are *Agriolimax laevis*, *Carychium minimum*, *Euconulus fulvus*, *Punctum pygmaeum*, *Succinea pfeifferi*, *Zonitoides nitidus*, *Limnaea truncatula*, and *L. palustris*. The habitat is usually in wild, mountainous or hilly country among rushes, sedges, and reeds.

178. Goodey, T. (1933). "*Anguillulina graminophila* n.sp., a nematode causing galls on the leaves of fine bent-grass." J. Helminth. 11: 45–56.

On *Agrostis tenuis* at St Albans. Often associated with galls is a fungus *Dilophospora alopecuri*. A similar co-parasitism has been observed elsewhere between this fungus and the nematode *A. tritici* on wheat, spelt and rye.

(*d*) Islands

See also **201, 205**

179. Dowdeswell, W. H. (1936). "The Lepidoptera of Cara Island." Entomologist, 69: 49–53.

Ten species of butterflies and 22 species of moths were caught on this small island near the mainland of the Mull of Kintyre.

3. ANIMAL BEHAVIOUR AND THE ACTION OF ENVIRONMENTAL FACTORS

See also **163, 237, 252**

180. Wyllie Fenton, E. (1936). "The problem of moor mat grass." Scottish J. Agric. 19: 143–8.

Intense sheep grazing favours mat grass (*Nardus stricta*) as against more nutritious grasses. One effect of this is the spread of *Nardus* from centres round peat hags. Observations and experiments are described. The author maintains that grazing areas dominated by *Nardus* are produced by selective sheep grazing together with incorrect burning techniques and natural processes of succession. He suggests that afforestation is the only way to rejuvenate some areas of this sort.

181. Anon. (1936). "Highways and hedgerows." Bird Notes and News, 17: 2–4.

The views of a number of correspondents on trimming roadside hedges and its effect on bird life. This cutting of grass and other vegetation on roadsides during the nesting season seems to be the cause of considerable mortality among various species and the need for some form of control is indicated.

182. Kennedy, P. G. (1936). "Roosting habits of the tree-creeper." British Birds, 30: 2–13.

Detailed description and photos of roosting in holes made in *Wellingtonia* and other trees. Each bird appears to have choice of many different holes.

183. Alexander, H. G. (1936). "The movements of sea-birds." British Birds, 29: 298–9.

Notes on local movements of divers, guillemiots and scoters in English Channel, their relation to wind, tides currents, and feeding grounds.

184. Eltringham, W. (1936). "Jottings from Crawcrook." Vasculum, 22: 24–5.

Nesting material dropped by herons below the nest is taboo. Grebes consume large quantities of sticklebacks. Over a wide area in the autumn of 1935 there were no acorns, beech-mast, haws and mountain ash berries, possibly the result of the late frost in May. Throws doubt upon statements that the frog hibernates in mud under water. Records finding one in nest of "moss bee", and quotes others being found in greenhouses and under damp leaves.

185. H[arrison], J. W. H. (1936). "Toads and their breeding habits." Vasculum, 22: 77–8.

Vast numbers, mostly mated, but many single, were observed at a pond near Oxclose in March. In several cases, hugh masses of males were around one female; in one group the number of males was 16, and in another, 22! The females involved were both dead.

186. Savage, R. M. (1935). "The influence of external factors on the spawning date and migration of the common frog, *Rana temporaria temporaria* Linn." Proc. Zool. Soc. Lond. 49–98.

A mass of phenological and meteorological data are analysed and a hypothesis made to explain why frogs leave their winter hibernating ponds for the spawning ponds. It is suggested that they are attracted by a specific smell associated with the right conditions for spawning. The frogs wait about, making no noise, until the crucial moment arrives when a change takes place in the algal flora of the ponds, induced by meteorological factors. Spawning and croaking then begin. There is some correlation between time of spawning and phosphate changes in ponds.

187. Savage, R. M. (1935). "The ecology of young tadpoles, with special reference to some adaptations to the habit of mass-spawning in *Rana temporaria temporaria* Linn." Proc. Zool. Soc. Lond. 605–10.

Tadpoles live for the first few days after hatching in an environment greatly deficient in O_2, which would be lethal but for the swimming movements found to be present even in very young individuals. These movements are more evident as tadpoles grow older. Young tadpole aggregations remain intact because the peripheral individuals tend to remain motionless in more or less well aerated water.

188. Boycott, A. E. (1936). "Frogs in winter." Vasculum, 22: 79.

Six frogs hibernating in mud in cement tanks in garden.

189. Fox, H. Munro (1936). "Metabolism of cold-blooded animals in different latitudes." Nature, 137: 903–4.

Comparison of metabolic rates of closely related species at the Kristeneberg (Sweden) and Plymouth stations showed that the O_2 required for locomotion is higher in warmer water species. Respiratory movements among Crustacea correspond to the locomotory findings.

190. Washbourn, R. (1936). "Metabolic rates of trout fry from swift and slow-running waters." J. Exp. Biol. 13: 145–7.

Individuals of *Salmo fario* from swift-running water were found to have a respiratory rate higher than those of slow-running water.

191. Savage, R. E. & Wimpenny, R. S. (1936). "Phytoplankton and the herring. Part II. 1933 and 1934." Ministry Agric. Fish., Invest. Ser. 2, 15, No. 1: 1–88. (London: H.M. Stationery Office. Price 4*s*. 6*d*.)

Unusually large patches of diatoms of two species occurred in the North Sea in 1933 and 1934. The masses were shown to move with the currents as deduced from isohalines. Influx from the north of bottom water rich in nutrient salts appears to have favoured this growth in 1933. The maximum densities per cu.m. were: *Rhizosolenia styliformis* 1,377,300 cells; *Biddulphia sinensis* 2,487,900 cells. The arrival of the East Anglia herring shoals was delayed by the presence of these patches against the edges of which the fish were massed. Zooplankton were also aggregated against the edges though in different places. It is suggested that conditions within a patch are favourable to young zooplankton and other juvenile animals. High salinities in 1933 may possibly have been caused by abstraction of water during algal growth or by reaction of living organic matter with the titrating salt.

192. Gunn, D. L. & Notley, F. B. (1936). "The temperature and humidity relations of the cockroach. IV. Thermal death-point." J. Exp. Biol. 13: 28–34.

Experiments with *Blattella germanica*, *Blatta orientalis*, and *Periplaneta americana* showed that after 24-hour exposures to constant temperature conditions in moist air there were few deaths below 37° C., and few survivals above 39° C. In dry air *P. americana* has the same threshold as in moist air (37–39° C.); *B. orientalis* has a dry air threshold of 34–36° C., while *B. germanica* showed a wide variation in results. After 1-hour exposures all animals were alive in moist air up to a maximum of 41° C., and in dry air at 43° C. The lowest temperatures at which none survived were

42° C. for *P. americana* and 42° C. for the others; in moist air, and 46° C. for *B. orientalis*, and 45° C. for the others. Moist air is therefore concluded to be more favourable than dry in long exposures, since death here is from desiccation; dry air is more favourable in short exposures since evaporation of water from the body lowers body temperature.

193. Buxton, P. A. & Mellanby, K. (1934). "The measurement and control of humidity." Bull. Ent. Res. 25: 171–5.

Describes a simple paper hygrometer for use in confined spaces; also methods for controlling humidity by means of solutions of KOH, supersaturated salt solutions, and solution of H_2SO_4 in water, for use where pure sulphuric acid is not available.

194. Pinchin, R. D. & Anderson, J. (1936). "On the nocturnal activity of Tipulinae (Diptera) as measured by a light trap. (1) The time of flight and proportion of sexes." Proc. R. Ent. Soc. Lond. (A) 11: 69–75.

2092 specimens, representing 11 species, were captured in 1933 and 1934. The maximum activity is at dusk after which the activity falls to a constant figure about an hour before midnight. Females are most active at dusk, the males an hour later. There is a decrease in the activity of both sexes at dawn. Twice as many males as females were captured, but this is due mainly to a greater number of males in certain species, in one of which the female is wingless.

195. Pinchin, R. D. & Anderson, J. (1936). "On the nocturnal activity of Tipulinae (Diptera) as measured by a light trap. (2) The influence of temperature, cloud and moonlight on the numbers of insects captured." Proc. R. Ent. Soc. Lond. (A) 11: 75–8.

Minimum temperature is an important factor in determining the activity of *Tipula paludosa*. The numbers of Tipulinae captured are greatest on nights in the no-moon week of the lunar month which have over 90% cloud, and are least on nights in the full-moon week which have under 10% cloud. Between the two extremes there is a steady gradation, depending on the moon and cloud conditions.

196. Marshall, J. F. & Staley, J. (1936). "Exhibition of 'autogenous' and 'stenogamous' characteristics by *Theobaldia subochrea*, Edwards (Diptera, Culicidae)." Nature, 137: 580–1.

Observations show that members of this species are able to breed in very small cages and lay fertile eggs without first having devoured blood. Other mosquitoes illustrating the former phenomenon include *Aedes aegypti*, and *Anopheles maculipennis* var. *atroparvus*.

197. Hooper, C. H. (1935). "Pears—their pollination, the relative order of flowering of varieties, their cross fertilization and the insect visitors to the blossoms." J. S.-E. Agric. Coll. Wye, No. 36: 111–18.

Contains a useful table of the duration of flowering and dates for different varieties of pear, with references to other work. States necessity for insect pollination, without detailed evidence. Insects observed over several years (no species names given): 212 hive bees, 14 bumble bees, 13 smaller wild bees, 19 blue bottle flies, 10 other flies, 2 queen wasps, 1 butterfly, 2 midges. Concludes that hive bees are most important. Advises having bee-hives in pear orchards, since bumble bees do not seem important visitors to pears.

198. Nixon, G. E. J. (1936). "Notes on wasps. (V.)" Ent. Mon. Mag. 72: 6–8.

Reactions of a queen *Vespa vulgaris* L. towards an incipient colony of her own species with which she was brought into contact.

199. Boyd, D. O. (1936). "Two examples of unusual behaviour in Bombidae (Hym.)." J. Soc. Brit. Ent. 1: 129–30.

A worker *Bombus pratorum* visited only flowers (foxgloves) from which the corollas had fallen. worker *B. lucorum* consistently robbed the flowers while others visited them in the normal way.

200. Andrewes, H. L. (1936). "Honey-combs as a bait for moths." J. Soc. Brit. Ent. 1: 141–5.

Honey attracts not only most or all of the species that one would expect at "sugar", but several of genera that are rarely or never captured that way. Some moths thought to be scarce or absent in the author's district turned out to be quite common.

201. Harrison, G. H. (1936). "Larvæ of the currant moth (*Abraxas grossulariata*)." Vasculum, 22: 34.

On Barra (Outer Hebrides), and Canna (Inner Hebrides), where the larvae feed on heather, they were yet active in November, while on the mainland they were hibernating in October.

202. Harrison, J. W. H. (1936). "Black larvæ of the ribband wave (*Acidalia aversata*)." Vasculum, 22: 33.

Quite a number of Geometrid moths give rise to black larvae in the Tyne drainage area.

203. Foxon, G. E. H. (1936). "Orientation of *Chirocephalus* and *Daphnia*." Nature, 137: 948–9.

Experimentation with narcotized *Chirocephalus* show that the inverted position is probably caused by the shape of body. In *D. magna* and *D. pulex* orientation was apparently a function of gravity on the body shape and posture; the second antennae are important in orientation of *Daphnia*.

204. Triffitt, M. J. & Hurst, R. H. (1935). "On the thermal death-point of *Heterodera schachtii*." J. Helminth. 13: 219–22.

Experiments to find out whether potatoes could be disinfected by heat. The cysts are killed by exposure to 116° F. over 45 min. or more. Shorter exposures retard hatching considerably. 110° C. for up to an hour has no retarding effect. It is uncertain how far potatoes could withstand the high temperatures necessary for disinfection.

4. PARASITES

See also **165, 178, 248**

205. Elton, C. (1936). "Parasites from rodents and shrews in the outer Hebrides." Ent. Mon. Mag. 72: 31–4.

A parasite survey of mice (*Apodemus hebridensis* and *Mus musculus*) at Stornoway, Lewis and the Isle of Pabbay in the Sound of Harris.

206. Thompson, G. B. (1936). "The parasites of British birds and mammals. VII. Records of Ixodoidea from hedgehogs and their nests." Ent. Mon. Mag. 72: 116–18.

207. Thompson, G. B. (1936). "The parasites of British birds and mammals. VIII. Some additional records of bat parasites." Ent. Mon. Mag. 72: 133–6.

208. Hamilton, A. G. (1936). "Miscellaneous observations on the biology of *Apanteles glomeratus* L. (Braconidae)." Ent. Mon. Mag. 72: 24–7.

See 1936, *J. Anim. Ecol.* 5: 206. Further observations, the relation of the instars of the parasite to those of the caterpillar and the effect of parasitism upon the growth of the caterpillar.

209. Butler, C. G. (1936). "The occurrence of the Chalcids *Encarsia partenopea* Masi and *E. tricolor* Förster in England (Hymenoptera)." Proc. R. Ent. Soc. Lond. (A) 11: 79–80.

These are parasites of the cabbage white fly.

210. Salt, G. (1936). "Miscellaneous records of parasitism—II." J. Soc. Brit. Ent. 1: 125–7.

Records parasites of the fly *Phorbia genitalis* and of the willow sawfly *Pteronidea salicis*.

211. Oldham, J. N. (1935). "Further observations on the incidence of parasitism of flea beetles by the nematode, *Howardula phyllotretae*." J. Helminth. 13: 163–6.

Continues observations on various species of *Phyllotreta* (*atra, cruciferae, nigripes, undulata,* and *vittula*). In 1931–3 *P. nemorum* from Hertfordshire and Schleswig-Holstein were quite free from parasites. A table gives percentage infection of the other five species in 1931–3. This varied much from year to year (but not always parallel in different species), e.g. *P. undulata*: 1931, 74%; 1932, 60%; 1933, 24%. Infection with Hymenopterous parasites was low, never more than 4%. Detailed figures are given, but no species named. They seldom occurred in company with the worms, viz. only 4 cases out of 3400.

212. Oldham, J. N. (1933). "On *Howardula phyllotretae* n.sp., a nematode parasite of flea beetles (Chrysomelidae; Coleoptera), with some observations on its incidence." J. Helminth. 11: 119–36.

Phyllotreta undulata, P. nemorum, P. cruciferae, P. atra and *P. nigripes*, British and German material. The worms cause reduced development and fecundity, and sometimes sterility and death, in the adult beetles. The percentage infection varied from 0 to 76%.

213. Southwell, T. (1933). "Helminthology in its applications to marine fisheries." J. Helminth. 11: 63–6.

Refers only to cestodes. Stresses our meagre knowledge except in certain well-worked areas. Adult tapeworms live mostly in the spiral valves of Elasmobranchs, which can partly reduce infestation by calcification of tissues round the worm's head. The larvae live in many marine animals and are common in bony fish, often in mesentery. Very few life histories are known completely. Tapeworm larvae are thought to cause pearl formation in Ceylon pearl oysters: the adult lives in sharks and rays that eat the oysters.

5. FOOD AND FOOD-HABITS

See also **184, 197, 199**

214. Hibbert-Ware, A. (1936). "Report of an investigation of the food of captive little owls." British Birds, 29: 302–5.

Experimental feeding of mice and sparrows to little owls (*Athene noctua*) showed that all bones and indigestible matter were evacuated in pellets. With a diet of earthworms no pellets were produced.

215. Hendy, E. W. (1935). "The little owl: an enquiry." Discovery, 16: 302–4.

A discussion of the two main viewpoints on the food-habits of the little owl (*Athene noctua*): (*a*) that it is dangerous to game-birds, (*b*) that it feeds mainly on rodents and insects. Reproduces useful map of British Field Sports Society showing counties where this owl is wholly or partly protected (the greater part of England). Contains a few of the author's own observations. Concludes that (*b*) is mainly right, but that occasional damage occurs.

216. Tully, H. (1936). "The little owl in Northumberland and Durham." Vasculum, 22: 41–5.

Discusses the status of the little owl in these counties and concludes that it is now a resident species. Gives evidence of it taking thrushes or blackbirds, larks, tree sparrows, snipe, redshank, long-tailed field mice and a worm. States that if birds are available they are taken as freely as rodents and no preference is shown for one or the other.

217. Ticehurst, C. B. (1936). "Examination of pellets of Montagu's harrier." British Birds, 29: 248–9.

Six Montagu's harrier pellets from Yorkshire contained snake scales, young grouse and golden plover, song-thrush, meadow-pipit, small passerine birds and field voles. Gives a technique for analysis of pellets of owls and hawks.

218. Clapham, R. (1936). "Blackgame and their food from August to December." The Gamekeeper, 39: 139–40.

The contents of 30 blackgame crops killed in Westmorland. Gives weights and sexes, also notes on grits in gizzards.

219. Moreton, B. D. (1936). "Crossbills' method of feeding on larch cones." British Birds, 30: 27–8.

Points out difference between crossbill and squirrel feeding methods.

220. H[arrison], J. W. H. (1936). "Hebrew character moths and tits." Vasculum, 22: 77.

A considerable number of these moths (*Taeniocampa gothica*) were liberated in a garden and, within half an hour, crowds of tits (including the blue, coal and great tit) put in appearance, and in a "twinkling" the whole of the moths were eaten.

221. Armitage, J. (1935). "Lapland and other buntings on the Pennines in winter." British Birds, 28: 230–2.

The birds are attracted by the seeds, and by gall-midge larvae in the haulms, of moor grass (*Molinia*). Notes on species seen in winter of 1933–4.

222. Roebuck, A. (1936). "Birds in agriculture: specific examples of their usefulness." Bird Notes and News, 17: 8–10.

Examples of several species of birds eating insects and weeds proved to be harmful to farm and garden crops.

223. Thomas, J. F. (1936). "The food of nestling swallows." British Birds, 29: 244–5.

Insects (Diptera and Hymenoptera) brought to nestlings by parent swallows in Carmarthenshire, 1935.

224. Carrick, R. (1936). "Experiments to test the efficiency of protective adaptations in insects." Trans. R. Ent. Soc. Lond. (A) 85: 131–9.

Various insects were placed near the nests of wren, whitethroat, willow-warbler and sedge-warbler. It was found that predation was not random, but highly selective. Detailed procryptic resemblances were successful as a means of escaping, but movement at once destroyed their protective value.

225. Payne, L. G. (1936). "The natterjack toad. A local British species." London Nat. for 1935: 83–7.

Rather general notes on food and habits, mostly based on captive toads, directions being given for keeping them. "The food...consists principally of crepuscular beetles." A good photograph of natterjacks.

226. O'Donoghue, C. H. & Boyd, E. M. (1934). "A third investigation of the food of the sea trout (*Salmo trutta*), with a note on the food of the perch (*Perca fluviatilis*)." Fisheries, Scotland, Salmon Fish., 1934, No. 2: 1–21. (Edinburgh: H.M. Stationery Office. Price 1*s.* 3*d.*).

Whiting, lemon sole, dab and two species of Crustacea are added to the list of food animals. Sand-eels were of one species only: *Ammodytes tobianus*. In July and August there was a decrease

in the numbers of parasitized fish. It is concluded that the perch might become a serious competitor for the food of the brown trout. 260 sea-trout and 9 perch were examined, from the region of Montrose in Angus.

227. Norris, M. J. (1936). "The feeding-habits of the adult Lepidoptera Heteroneura." Trans. R. Ent. Soc. Lond. 85: 61–90.

The principal food of butterflies is the nectar of flowers, but how far this is true of moths is doubtful. Very little is known about the feeding habits of the Microlepidoptera, but flowers are visited by many Noctuidae, some Geometridae, most Sphingidae and by the Lithosiinae. Flowers may be found by sight or scent. Highly smelling sugary substances besides nectar are fed upon by Lepidoptera with a highly developed olfactory sense. Some Noctuidae pierce the rind of sound and even unripe fruit in order to suck the juices. Water-drinking in Lepidoptera is almost entirely confined to the male sex and is inextricably confused with that of their attraction to dung and perspiration of animals.

228. Norris, M. J. (1934). "Contributions towards the study of insect fertility.—III. Adult nutrition, fecundity and longevity in the genus *Ephestia* (Lepidoptera, Phycitidae)." Proc. Zool. Soc. Lond. 333–60.

Ephestia kühniella (which lives almost entirely in flour mills) exists normally without water; but a closely allied species with a less restricted habitat (*E. cautella*) dies prematurely without water. Experiments on effects of water, sugar and albumen upon egg production and length of life. Summary of literature on food requirements of mature insects, especially of Lepidoptera. A table illustrates the evolutionary trend towards complete emancipation from adult feeding.

229. Huggins, H. C. (1936). "Unusual food-plant of *Sesia cynipiformis*." Entomologist, 69: 16–17.

Black poplar. The usual plants are oak, birch, and elm.

230. Parkin, E. A. (1936). "A study of the food relations of the *Lyctus* powder-post beetles." Ann. Appl. Biol. 23: 369–400.

Starch, sugars and protein are necessary constituents of the larval food. Larvae have been reared to the imaginal stage on a diet which contains no wood. Larvae are unable to develop in wood from which starch is absent. The presence of relatively little starch retards development.

231. Fletcher, T. B. (1936). "Wasps as enemies of butterflies." Ent. Rec. 48: 10–11.

Whole broods of caterpillars of *Vanessa io* and *Aglais urticae* were wiped out during the hot, dry, summer of 1935 when an unusually intensive search for insect prey was made. Thousands of blue butterflies (*Polyommatus coridon* and *P. icarus*) were attacked while resting in the evening on grasses and flower heads. See also **S. G. Castle-Russell** (1936, *ibid.* 48: 50–1) and **C. Nicholson** (1936, *ibid.* 48: 64–5).

232. Mosely, M. E. (1936). "Imaginal Trichoptera apparently feeding." Entomologist, 69: 63.

Drusus nigrovectus sipping nectar.

6. ANIMAL POPULATIONS

See also **181, 228, 267**

233. Delap, P. (1936). "Deer in Wicklow." Irish Nat. J. 6: 82–8.

In Powerscourt Deer Park on the edge of the Wicklow mountains, on 1000 acres, there are 60–65 red deer, 12–25 fallow deer, and 500–600 Japanese deer. The red deer and fallow deer occupy limited areas. The Japanese are all over, having been introduced over 60 years ago. The land is overstocked, 200 deer having died in winter 1932–3 and 1933–4, fewer in 1934–5, more again in 1935–6. The red deer herds were mapped over 3 years, but few details are given. This

study included 40 deer outside the park. Japanese deer have not established outside, the few that exist returning annually for rutting season. Few fallow deer have established outside, but a park at Ashford has many outside. The author stresses the need for rational management by shooting deer, in order to prevent over-population. This has apparently not been done in Wicklow. There is no mention of disease, but some notes on deterioration in antlers.

234. Rooke, K. B. (1936). "Birds seen in the North Atlantic, August and September, 1935." British Birds, 29: 366–77.

Records of birds seen, with some counts and exact positions, on two crossings of Atlantic between Liverpool and St John's, Newfoundland.

235. Wynne Edwards, V. C., Lockley, R. M. & Salmon, H. M. (1936). "The distribution and numbers of breeding gannets (*Sula bassana* L.)." British Birds, 29: 262–76.

Summary of world data on gannet colonies with counts or estimates of numbers at each. Nineteen colonies known with a total estimated population of about 156,000 gannets.

236. Levett, M. J. (1936). "Fulmar petrels on the Northumberland coast." Vasculum, 22: 69–72.

This bird has established itself in several breeding colonies on the coast of Northumberland and is steadily increasing.

237. Hollom, P. A. D. (1936). "Great crested grebe report." London Nat. for 1935: 87–9.

Records 1935 census in London area. Total number of birds counted in 1935 was 168, compared with 171 in 1931, i.e. little change. But the number of breeding pairs had decreased from 68 to 42. The large non-breeding and somewhat fluctuating population on the large Thames Valley reservoirs was not included in these figures. Decrease occurred both on drought affected areas and on Lea Valley reservoir which had not been affected. An aerial survey was used to find gravel pits, which are often used by grebes; but only for a few years, as the pits get filled up.

238. Van Someren, V. D. (1936). "Territory and distributional variation in woodland birds." Scottish Nat. 35–45.

Rough census counts by walking a 5 or 6-acre deciduous wood (lime, sycamore, yew, with undergrowth of grass, nettle, raspberry or dense rhododendron), in Midlothian, by one observer on 14 dates between 19 January and 22 April, 1933, gave numbers of individuals varying between 43 and 157, but numbers of species varying only between 8 and 17—in 11 cases between 12 and 15. The total number of species noted was 25, including two winter migrants. The position of singing males in spring, except in the case of the song thrush, was not a good indication of nesting territories. Birds move about into the wood, away from wind, to a great extent on different days. Weather also affects singing activity. Some of the technical errors in such census work are noted.

239. Barnes, M. D. (1936). "The death-roll of birds on our roads." Naturalist; 85–6.

A count of all dead birds seen on roads while cycling about 4000 miles during 1935. 940 seen, mainly sparrows, finches, yellow-hammers, thrushes, blackbirds and larks. The greatest number was seen in July, especially on roads closely bordered by hedgerows.

240. Midlothian Ornithological Club (1936). "A census of rookeries in Greater Edinburgh." Scottish Nat. 53–6.

3060 nests were counted in 1935, for comparison with earlier censuses in 1928 (2376 nests) and 1921 (1547 nests). Thus the total population had doubled in 14 years, in spite of a considerable extension of building operations in the area, which has caused several large rookeries to decrease.

241. Gent, C. J. (1936). "Notes on the movements and roosting habits of rooks in south Northumberland. With special reference to the Gosforth District." Vasculum, 22: 26–9.

The change from mid-winter habits (i.e. flying in nightly to a central roost) to roosting in the rookery during the spring is a very sudden one, the third week in March being the vital period. The change-over in the autumn would appear to be more gradual.

242. Burkitt, J. P. (1936). "Young rooks, their survival and habits." British Birds, 29: 334–8.

Field observations indicate that great mortality occurs in July and August, leaving only about one-tenth as many young as adults by autumn.

243. Graham, Michael (1935). "Modern theory of exploiting a fishery, and application to North Sea trawling." J. Cons. Int. Explor. Mer. 10: 264–74.

Comparison of data of the North Sea fisheries before and after the War. Analysis of fisheries research and yearly hauls shows that a moderately decreased fishing rate would do little towards decreasing the weight yield or enabling the fish population to grow to greater weights and to increase in number.

244. Nall, G. H. (1936). "Sea-trout of the Kyle of Sutherland district, 1934–35." Fisheries, Scotland, Salmon Fish., 1936, No. 1: 1–28. (Edinburgh: H.M. Stationery Office. Price 2*s*.).

Condition was better in 1935 than in 1934. Comparative data from some 20 other Scottish districts indicate that: (1) Smolt age decreases from north to south. Here 62·4% migrate after 3 years of parr life. (2) Length at migration is one of the three lowest of all districts tested. (3) Growth-rate in the sea is about the average for the east coast. (4) Only 6·2% spawn as whitling (third lowest).

245. Nall, G. H. (1936). "Sea-trout of the Laxford system (Loch Stack and Loch More)." Fisheries, Scotland, Salmon Fish., 1936, No. 2: 1–23. (Edinburgh: H.M. Stationery Office. Price 1*s*. 6*d*.)

Lengths of smolts and whitling are above the Scottish average, but sea-growth here is slower than in any other district except the Ewe. Condition in all groups was better in 1935 than in 1934.

246. Macfarlane, P. R. C. (1935). "Salmon of the River Tay, 1934." Fisheries, Scotland, Salmon Fish., 1935, No. 5: 1–22. (Edinburgh: H.M. Stationery Office. Price 1*s*. 3*d*.).

Numerically the chief groups of the season's catch were small summer fish (39·4%) and grilse (35·9%). The average sizes of the adults are again shown to be larger than in any of the other districts investigated. Condition in 1930 was better than in 1934.

247. Richards, O. W. (1936). "Some quantitative methods for analysis of insect associations." Proc. Linn. Soc. Lond. 146: 33–6.

Frequency of eggs laid on individual cabbage plants is used as an index of abundance. By treating each plant as a "quadrat", the first generation eggs were found to have a random distribution, while the second showed a wide divergence from the random. The "minimal area" of a host-parasite complex is defined as "the smallest area in which it is likely that all alternative hosts and parasites will occur"; it will probably be rather large.

248. Ullyett, G. C. (1936). "Host density and the success of entomophagous parasites." Nature, 137: 742–3.

By experimental data and theoretical analysis it was found that the area searched by the Chalcidid parasite *Microplectron fuscipennis* varied inversely as the density of the host (*Diprion polytomum*), and that this searching is at random. The principle is apparently not affected by climate nor the presence of unsuitable host-individuals.

249. Barnes, H. F. (1936). "Insect fluctuations; population studies in the gall midges (Cecidomyidae)." Ann. Appl. Biol. 23: 433–40.

Discussion of studies published in *J. Anim. Ecol.* 1932–5, based on the chances of the insects reaching maturity when once they have reached a definite point in their life cycle, e.g. emergence period, egg-laying period, growth period and period of development.

250. Roebuck, A. (1936). "Fluctuations of insect populations: field observations." Ann. Appl. Biol. 23: 441–4.

Examples of sudden irruptions include *Andrena fulva*, *Blennocampa pusilla*, *Trochilium apiforme*, *Hylemyia brunnescens*, and *Psylliodes chrysocephala*. Examples of more stable species include *Phyllodecta vulgatissima*, *Psila rosae*, chafer beetles and *Pegomyia hyoscyami* var. *betae*.

251. Fidler, J. H. (1936). "Some notes on the biology and economics of some British chafers." Ann. Appl. Biol. 23: 409–27.

It is suggested that regular flight-years, such as occur on the Continent, do not occur in the British Isles because of the differences in climatic conditions, particularly in spring.

252. Harrison, J. W. H. (1936). "The scarcity of the gray chi (*Polia chi*) locally during 1935." Vasculum, 22: 33.

Although normally exceedingly abundant in the Team Valley, only a few specimens were seen in 1935. Almost certainly the young larvae had been killed by the heavy May frosts soon after hatching.

253. Donisthorpe, H. (1936). "The oldest insect on record." Ent. Rec. 48: 1–2.

A queen ant, *Stenamma westwoodi*, which died after being in captivity for 14 years and 12 days. It is probable that she was 18 years old when she died and certainly over 16 years.

254. Wright, F. S. (1936). "Report on the Maldon (Essex) periwinkle fishery..." Ministry Agr. Fish., Fish. Invest. Ser. 2, 14, No. 6: 1–37. (London: H.M. Stationery Office. Price 2*s*.).

A bye-law of 1898 permits the collection of periwinkles by hand only. It was desired to find out how far dredging operations would deplete the stock. The mud-flat population was estimated as only 12 individuals per sq. m. in December 1931, compared with 39 in October 1931 and 25 in April 1932. Tidal pools contained fewer animals in October and April than in December due to immigration from the banks for the winter. The density of the channel population was estimated (October 1931) as 14 per 100 sq. ft. There were (e.g. in April 1932) two size groups on the mud-flats: 12 and 23 mm. modal length, ages about 1 and 2 years. In the channel only one size group was found (15–34 mm.) of which one-third had badly eroded shells. These latter were the three-year class which probably reaches the age limit. The channel population is derived from the mud-flats by migration on a scale sufficiently large to support commercial dredging operations. In 1931–2 there was a scarcity of marketable sizes (over 20 mm.).

255. Bunting, L. E., Eslick, A., Jones, J. W. & Orton, J. H. (1936). "Rate of growth of *Cardium edule*." Nature, 137: 705–6.

Examination in 1935 and 1936 of *Cardium* individuals in an artificial marine lake at Wallasey created in 1933 showed that this species is able to live successfully when totally submerged. The bulk of the population is assigned to the spatfall of 1933. From the findings it is contended that a depleted bed may be recovered in three years.

256. Shrubsole, G. (1936). "Apparent disappearance of *Limnaea peregra* from Fiston pond, Eastbourne Downs." J. Conch. 20: 217–18.

This species decreased in numbers after the introduction of *Limnaea stagnalis*.

257. Orr, A. P. (1934). "On the biology of *Calanus finmarchicus*. Part IV: Seasonal changes in the weight and chemical composition in Loch Fyne." J. Mar. Biol. Ass. U.K. 19: 613–32.

Dry weight of males, females, and stage 5 individuals fluctuates greatly throughout the year, stage 5 individuals in May weighing one-third their December weight (per 100 individuals). Stage 5 individuals are largest and heaviest when most abundant. Fluctuations in fat and protein content are correlated with seasonal dry weight variation.

258. Bogorov, B. G. (1934). "Seasonal changes in biomass of *Calanus finmarchicus* in the Plymouth area in 1930." J. Mar. Biol. Ass. U.K. 19: 585–612.

Three "seasons" of the year are recognized, characterized by biomass differences: a spring (May) maximum followed by a summer (June-September) decline to the autumn-winter (October–April) minimum.

7. MIGRATION, DISPERSAL, AND INTRODUCTIONS

See also **183, 191, 233, 241, 244, 254**

259. Witherby, H. F. (1936). "The 'British Birds' marking scheme. Progress for 1935." British Birds, 29: 339–44.

46,430 birds ringed in British Isles during 1935. Records of numbers ringed by different people and numbers of each species ringed.

260. Anon. (1936). "Recovery of marked birds." British Birds, 29: 277–83 and 310–20.

Records of recovery during 1935 in British Isles and abroad of birds ringed in British Isles.

261. Thomas, J. F. (1936). "Results of ringing and trapping swallows in Carmarthenshire." British Birds, 29: 245.

Some records of swallows ringed in 1934 returning in 1935 to same breeding places. Number ringed and recovered not stated. One male ringed in 1931 caught in same place in 1935.

262. Lockley, R. M. (1936). "Skokholm bird observatory." British Birds, 29: 222–35.

This island of about 240 acres off the coast of Wales has now been given up entirely to bird observation. A full sized Heligoland ringing trap has been erected. *Bona fide* ornithologists can obtain accommodation and facilities for bird observation. Funds for maintenance are needed. A list of birds seen on the island is given.

263. Hendy, E. W. (1935). "Spring migration of birds in Western England." Discovery, 16: 65–7.

Enquiries carried out through bird watching and preservation societies in Devon and Cornwall, and printed weekly with a map (and later summarized) in the *Western Morning News*, are here reviewed.

264. Delamain, J. (1936). "Movements of jays in France." British Birds, 29: 297–8.

Large scale southerly movement of jays in south-west France in September and October, 1935. Similar movements were also seen in England at this time. A Continental jay was recorded in Essex in December, 1935, by **J. W. Campbell**, *ibid.* 324.

265. Ward, J. H. (1936). "Rook roosts in the Manchester area." Naturalist: 153–6.

Data on winter flights. Birds from four roosts south of Manchester make daily flights to feeding grounds northwards over Manchester, some going at least 15 miles.

266. Bowman, A. & Rae, B. B. (1935). "Lemon soles (*Pleuronectes microcephalus*). Marking experiments in Scottish waters during the period 1919–1931." Fisheries, Scotland, Sci. Invest., 1935, No. 1: 1–42. (Edinburgh: H.M. Stationery Office. Price. 2*s*).

From 1919 to 1931 there were 1015 returns out of 7799 marked fish. Ripe males were taken throughout the year, ripe females only from March to October. Four definite spawning grounds were located from the Firth north to Shetland. 797 fish were "non-migrants". Among 218 "migrants" there was found a general "contranatant" course north up the east coast to the Orkneys and Shetlands, thence west or south-west. Migration (in some cases at a minimum rate of 2 miles per day) is most intense from December to March. Mortality due to marking operations was greatest in fish below 26 cm. The stock over this length will be fished out in not less than 4 years.

267. Lucas, C. E. (1936). "On the diurnal variation of size-groups of trawl-caught herring." J. Cons. Int. Explor. Mer. 11: 53–9.

It has previously been shown that trawled herring catches are usually larger by day than by night. This is further illustrated by figures for 1931–3. A paper by Fulton is reanalysed: it is found that the proportion of large to small fish is greatest at night. This may be due to migration of perhaps 90% of the small fish off the bottom at night. Certain figures suggest that this migration occurs under dull conditions by day: it may be correlated with plankton movements. The effect of this differential migration upon the statistical analysis of herring populations has not hitherto been realized.

268. H[arrison], J. W. H. (1936). "Migration of sticklebacks." Vasculum, 22: 78, 9.

Enormous numbers attempting to go up the River Wear through the arches of the New Bridge, near Chester-le-Street, in 1923 and "probably millions" in 1936. The pressure from behind was so great that they were cast ashore, some struggling back to the water, but many dying.

269. Williams, C. B. (1936). "Collected records relating to insect migration: third series." Proc. R. Ent. Soc. Lond. (A) 11: 6–10.

Contains some British records.

270. Dannreuther, T. (1936). "Migration records, 1935." Entomologist, 69: 1–6.

Contains general summary for 1935 and comparative estimates of abundance in 1935. Further references in *idem et ibid.* 12; **G. Heslop Harrison**, *ibid.* 60.

271. Garrett, F. C. (1936). "Migrant Lepidoptera in 1935." Vasculum, 22: 8–10.

In north-eastern England migrants were unusually scarce; hardly any were seen in the early summer, and although their numbers increased later they remained below the average. Five reports of the rare Camberwell beauty butterfly (*Nymphalis antiopa*) were received.

272. Williams, C. B. (1935). "Butterfly immigrants in Britain." Discovery, 16: 36–9.

A brief popular account giving a useful bird's-eye view of the subject. Rare visitors: Bath white from Mediterranean, Camberwell beauty from Scandinavia, Queen of Spain fritillary from Europe, monarch from North America. More frequent: clouded yellow and pale clouded yellow (with independent years of abundance) painted lady, red admiral. Also additions to such common residents as the whites.

273. Burkill, H. J. (1936). "British butterflies in 1935." London Nat. for 1935: 67–70.

Notes on abundance and occurrence of migrants.

274. Newcombe, A. O. (1936). "A Lepidopterist's contribution to problems of plant distribution." Vasculum, 22: 64–8.

Two diametrically opposed opinions have been put forward to explain the distribution of certain British plants, viz. that they are glacial relict forms and that they are recent additions, due to the agency of birds. The author points out that for an explanation to be completely satisfactory it must also account for the specialized distribution of other organisms such as invertebrates and mammals and then proceeds to discuss the distribution of six butterflies and moths, concluding that some are genuine glacial relicts, that others reached Britain from Scandinavia, and others across the North Sea area at the close of glacial times (to these could be added most of the Lepidopterous fauna). The means of dispersal would be those ordinarily recognized for the species under consideration. Although the author does not deny that some seeds are bird dispersed, he considers that the present distribution of British plants is better explained by other methods.

275. Davies, W. M. (1936). "Studies on the Aphides infesting the potato crop. V. Laboratory experiments on the effect of wind velocity on the flight of *Myzus persicae* Sulz." Ann. Appl. Biol. 23: 401–8.

Low wind velocities had a marked influence on flight which ceased when the speed of the wind was increased to 3·75 m.p.h. The aphides remained stationary when the high winds of 20 and 30 m.p.h. passed through the experimental chamber. Even in a gale of 70 m.p.h. the aphides adhered to the surface with ease, using a small membranous pad between each claw and another at the base of each tarsus. Voluntary migration and involuntary transportation are discussed.

276. Fraser, F. C. (1936). "Immigration of *Aeshna mixta* Latr. (Odonata) in 1935." J. Soc. Brit. Ent. 1: 117.

A large immigration arrived overnight at Bournemouth on 13 August, 1935.

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